Three-Dimensional poroelastic effects during hydraulic fracturing in permeable rocks
A fully coupled three-dimensional finite-element model for hydraulic fractures in permeable rocks is presented, and used to investigate the ranges of applicability of the classical analytical solutions that are known to be valid in limiting cases. This model simultaneously accounts for fluid flow within the fracture and rock matrix, poroelastic deformation, propagation of the fractures, and fluid leakage into the rock formation. The model is validated against available asymptotic analytical solutions for penny-shaped fractures, in the viscosity-dominated, toughness-dominated, storage-dominated, and leakoff-dominated regimes. However, for intermediate regimes, these analytical solutions cannot be used to predict the key hydraulic fracturing variables, i.e. injection pressure, fracture aperture, and length. For leakoff-dominated cases in permeable rocks, the asymptotic solutions fail to accurately predict the lower-bound for fracture radius and apertures, and the upper-bound for fracture pressure. This is due to the poroelastic effects in the dilated rock matrix, as well as due to the multi-dimensional flow within matrix, which in many simulation codes is idealised as being one-dimensional, normal to the fracture plane.
A Fully Coupled XFEM Model for Flow and Deformation in Fractured Porous Media with Explicit Fracture Flow

A hydro-mechanical model with explicit fracture flow is presented for the fully coupled analysis of flow and deformation in fractured porous media. Extended finite element method (XFEM) is utilised to model the fracture discontinuity in the two-dimensional plane-strain mechanical model. Two flow models, a one-dimensional laminar flow within the fracture and a two-dimensional Darcy flow through porous media, are considered. The flow domains are coupled through a mass exchange term (leak-off) accounting for discontinuous Darcy flow velocity across the fracture. Particular attention is given to the coupling of the flow domains with the mechanical model. Spatial and temporal discretisation is achieved using the standard Galerkin method and the finite difference technique, respectively. Unlike the successive coupled models where the results of the mechanical model is used to update the fracture flow model and vice versa, the fully coupled hydro-mechanical formulation is solved simultaneously. The model is verified against several closed form solutions from the literature. The impact of formation flow and leak-off flow on the fracture opening due to injected fluid pressure is discussed.

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A Three-Dimensional Numerical Model for Double Porosity Media with Two Miscible Fluids including Geomechanical Response

The finite-element formulation of a coupled fluid flow and geomechanics for two-phase fluid flow through fractured porous media is presented. Two porosities, pores and fractures, and five phases are introduced. The two fluids are taken as wetting and non-wetting. The governing equations are derived based on the theory of poroelasticity, the effective stress principle, and the balance equations of mass and momentum, taking into account the solubility of non-wetting fluid into wetting fluid. Spatial and temporal discretisation of the governing equations have been realised through Galerkin method and the finite difference technique, respectively. A three-dimensional numerical code has been developed and validated based on the previously published data in the literature. Various applications of the model have been demonstrated through three field-scale examples.
A three-phase XFEM model for hydraulic fracturing with cohesive crack propagation

A three-phase, hydro-mechanical model for hydraulic fracturing is proposed. Three phases include: porous solid, fracturing fluid, and host fluid. Discontinuity is handled using extended finite element method (XFEM) while a cohesive crack model is used as the fracturing criterion. Flow through the fracture is defined as one-dimensional laminar flow, and flow through the porous medium (host reservoir) is defined as two-dimensional Darcy flow. Coupling between two fluids in each space, fracture and pore, is captured through capillary pressure–saturation relationships, while the identical fluids in fracture and pore are coupled through a so-called leak-off mass transfer term. Coupling between fluids and deformation is captured through compatibility of volumetric strain of fluids within fracture and pore, and volumetric strain of the matrix. Spatial and temporal discretization is achieved using the standard Galerkin method and the finite difference technique, respectively. The model is verified against analytical solutions available from literature. The leaking of fracturing fluid into the medium and suction of porous fluid into the fracture around the tip, are investigated. Sensitivity analyses are carried out for cases with slow and fast injection rates. It is shown that the results by single-phase flow may underestimate the leak-off.

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Consolidation of unsaturated lumpy clays

Coupled flow-deformation analysis of consolidation in unsaturated lumpy clays is presented. The governing differential equations are discretised using the Galerkin method and the finite difference technique for space and time, respectively. Particular attention is given to the cross coupling coefficients arising from the pore scale deformation compatibility between micro and macro voids. Two examples are analysed: a one-dimensional soil column, and a strip footing acting on a two-dimensional medium of lumpy clay. A range of sensitivity analyses are performed using different values of degree of saturation and volume fraction of macro voids. All results are carefully analysed and salient features of consolidation in lumpy clays are highlighted. The significance of the cross coupling coefficients in the numerical results obtained are also examined.

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Projects:

Numerical modelling of near wellbore flow
Department of Applied Mathematics and Computer Science
Period: 01/07/2017 → 30/06/2020
Number of participants: 3
Phd Student:
Kadeethum, Teeratorn (Intern)
Supervisor:
Salimzadeh, Saeed (Intern)
Main Supervisor:
Nick, Hamid (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU)
Project: PhD

Production performance of radial water-jet drilled wells: a modelling and laboratory study
Department of Applied Mathematics and Computer Science
Period: 01/10/2016 → 30/09/2019
Number of participants: 4
Phd Student:
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Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU)
Project: PhD