Simulating hydraulic fracturing using finite-discrete element method (FDEM): Effects of pre-existing joints and lateral stress gradient

Murad S. Abuaisha, David Eaton, Jeffrey Priest, Ron Wong

To cite this version:

Murad S. Abuaisha, David Eaton, Jeffrey Priest, Ron Wong. Simulating hydraulic fracturing using finite-discrete element method (FDEM): Effects of pre-existing joints and lateral stress gradient. Geoconvention 2016, Mar 2016, Calgary, Canada. hal-02460792

HAL Id: hal-02460792

https://hal-mines-paristech.archives-ouvertes.fr/hal-02460792

Submitted on 30 Jan 2020

GeoConvention
Calgary • Canada • March 7-11 2016
OPTIMIZING RESOURCES

Simulating hydraulic fracturing using finite-discrete element method (FDEM): Effects of pre-existing joints and lateral stress gradient

Murad AbuAisha[1,2], David W. Eaton[1], Jeffrey Priest[2] and Ron Wong[2]

[1]Department of Geoscience, University of Calgary
[2]Department of Civil Engineering, University of Calgary

Summary

This paper presents a numerical simulation study of hydraulic fracturing, by combining continuum and discontinuum approaches using a finite-discrete element method (FDEM). Calculated results are consistent with analytical results and exhibit many empirical features of hydraulic fracturing, although our solutions rarely exhibit a simple bi-wing fracture geometry. The effects of pre-existing joints at and around the wellbore on fracture topology and treatment pressure are investigated. Furthermore, the effect of lateral stresses due to pre-existing joints around and close to the wellbore is investigated, by including fractures with an asymmetric geometry that do not intersect the wellbore.

Introduction

Solutions of stress distribution around a borehole provide a starting point for analysis of hydraulic-fracturing (HF) operations. In the simplest cases, these solutions are based upon assumptions of elastic, isotropic and homogeneous media; however, the presence of pre–existing fractures and weak bedding planes render such assumptions questionable, motivating a more general numerical simulation approach. Here, we make use of a technique (the Y-Geo code) that combines both the Discrete Element Method (DEM) and the Finite Element Method (FEM). The Y-Geo approach has the capabilities of simulating fluid–driven fractures in jointed/pre–fractured rock masses.

This contribution is organized as follows. First, two HF tests are simulated in an elastic continuous medium, considering both isotropic (Shmax = Shmin) and anisotropic (Shmax >> Shmin) far-field stress states. Next, tests are performed with different configurations of rock joints that intersect the wellbore. Thirdly, the presence of lateral stress gradients is considered by introducing joints in the medium that do not intersect the wellbore.

Method

The Y-Geo uses continuum mechanics principles and DEM techniques to describe the elastic deformation and the material failure process, respectively. Starting from a continuum representation by finite elements of the solid region in question, progressive fracturing is allowed to take place according to some fracturing criterion, thereby forming discrete elements, which may be composed of one or more deformable finite elements. Subsequent motion of these discrete elements and further fracturing of both remaining continuum and previously created discrete elements is then modeled (Munjiza et al. [1999]), (Munjiza [2004]) and (Mahabadi et al. [2012]). Fluid injection and pressure-driven fracture propagation are captured by a simplified approach based on the principle of mass conservation for a compressible fluid injected into a deformable solid. The model is hydro-mechanically coupled exclusively in the sense that variations in cavity volume, due to either rock elastic deformation or fracturing, affect the pressure of the compressible fluid, which, in turn, affects rock deformation and failure, Fig. 1.

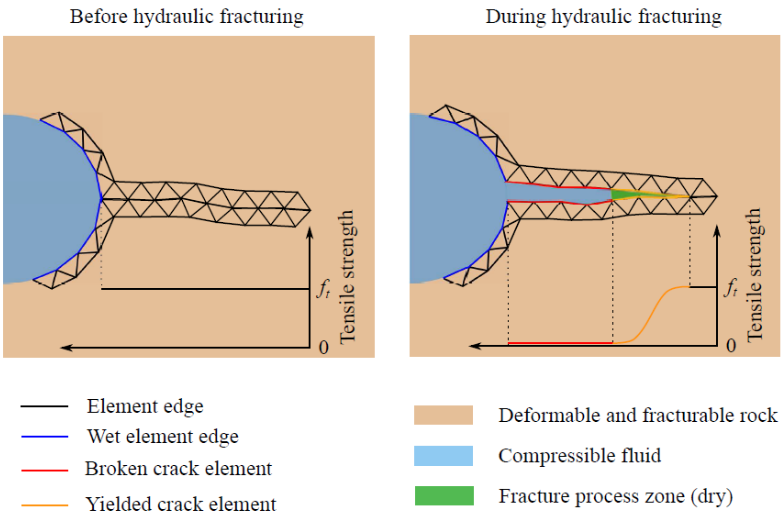

Figure 2. HF modelling using the FDEM. A tensile mode I fracturing is shown due to excessive fluid injection in the borehole. Only elements in concern are shown for simplicity.

Examples

Fluid-driven fracture topology is studied in isotropic and anisotropic far-field stress states. The effect of pre-existing joints on fracture evolution is also addressed.

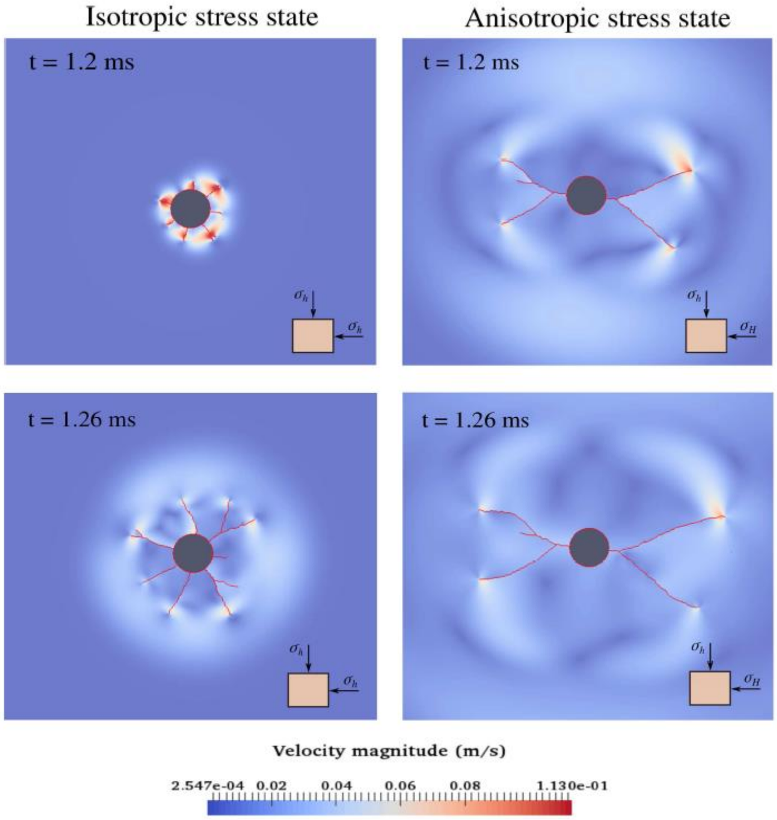

Figure 2. Fracture topology/trajectory for the cases of isotropic and anisotropic stress states and for two different time steps. The trajectories are plotted in the field of velocity magnitude.

Figure 2 shows the fracture trajectories for the two cases of isotropic and anisotropic stress states around a vertical wellbore. These trajectories are plotted in the field of velocity magnitude as an indication of the elastic wave spreading in the medium due to fracturing.

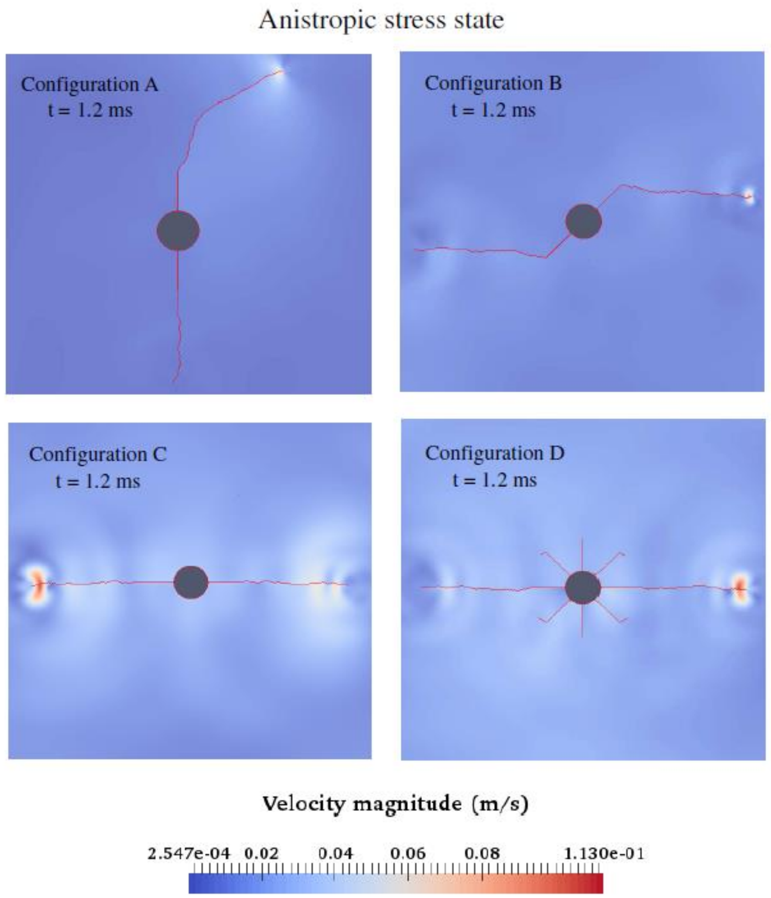

Figure 3. Fracture trajectories for different defect configurations at the wellbore. The trajectories are plotted in the field of velocity magnitude.

To study the effect of man-created joints on fracking pressure as well as fracture topology, the previous simulations, typically for the anisotropic stress state being the most common in field, are repeated by considering several defect configurations around the wellbore, Fig. 3.

Figure 4 shows fracture trajectories for three cases of defect orientations at distance 0.3L (L is the defect length) from the wellbore. Apparently, the presence of pre–existing defects close to the wellbore creates a perturbation to stress field (lateral stresses) which affects fracture evolution/topology.

Conclusions

The Y-Geo code is capable of tracking fluid-driven fractures topology in homogeneous and pre-fractured media. Consistent with HF observations, the study has shown that an isotropic stress state favours complex fracture growth compared with anisotropic stress state. Defects that are misaligned with the maximum stress produce fractures that initiate along the defect but subsequently rotate into the maximum stress orientation. The only scenarios considered that generated a simple bi-wing fracture; involve either wellbore defects combined with an isotropic far-field stress state or wellbore defects in the direction of maximum stress in anisotropic stress state. Stress gradients, introduced here by joints offset from the wellbore, lead to asymmetric fracture growth with a tendency for fractures to initiate in a direction away from the defect.

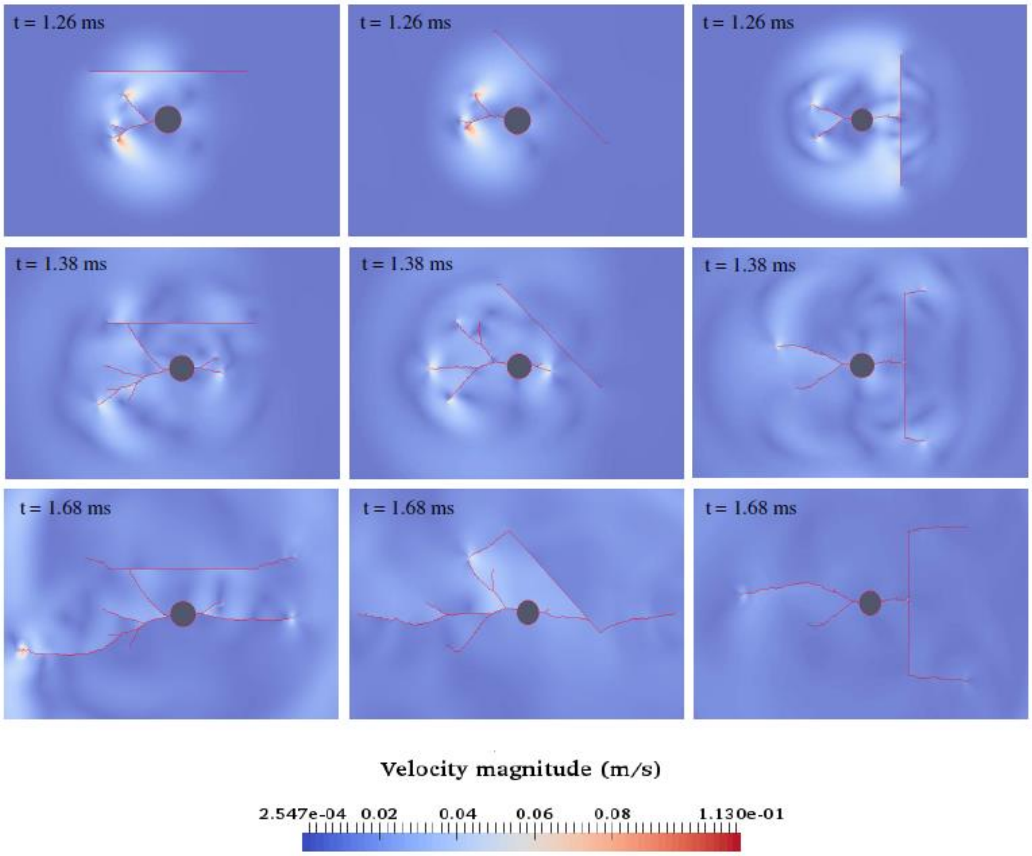

Figure 4. Fracture trajectories for three cases of defect configurations at time steps of 1.26, 1.38 and 1.68 ms and at some distance from wellbore. The trajectories are plotted in the field of velocity magnitude.

Acknowledgements

This work was funded by the Microseismic Industry Consortium and a Collaborative R&D grant from the Natural Sciences and Engineering Research Council of Canada.

References

Mahabadi, O.K., Lisjak, A., Munjiza, A., Grasselli G., 2012. Y-Geo: a new combined finite-discrete element numerical code for geomechanical applications, International Journal of Geomechanics, 12(6), 676-688.

Munjiza, A., Owen, D.R.J. and Bicanic, N., 1995. A combined finite-discrete element method in transient dynamics of fracturing solids, Engineering Computations, 12(2), 145- 174.

Munjiza, A., Andrews, K., and White, J., 1999. Combined single and smeared crack model in combined finite-discrete element analysis. International Journal for Numerical Methods in Engineering, 44(1), 41–57.

Munjiza, A., 2004. The Combined Finite-Discrete Element Method, John Wiley & Sons Ltd, Chichester, West Sussex, England.