Coupled Hydro-Geomechanical Simulation of Hydraulic Fracture Propagation in Naturally Fractured Reservoirs Using the Strong Discontinuity Approach

Leila Beserra*, Marcela Seixas*, Leonardo Guimarães*, Osvaldo Manzoli†

* Civil Engineering Department,
Federal University of Pernambuco
Recife, PE 50740-530, Brazil
e-mail: leila.brunet@ufpe.br, marcela.seixas@ufpe.br, leonardo@ufpe.br

† Civil Engineering Department,
São Paulo State University
Bauru, SP 17033-360, Brazil
e-mail: omanzoli@feb.unesp.br

ABSTRACT

Modeling hydraulic fracturing in the presence of a natural fracture network is a challenging task, due to the strong coupling that exists between fluid flow and mechanical behaviors, as well as the complex interactions between propagating fractures and existing natural interfaces. Understanding these complex interactions through numerical modeling is critical to the optimum design of stimulation strategies.

The geometry of the induced fracture is dominated by the rock's mechanical properties, in-situ stresses, and local heterogeneities such as natural fractures and weak bedding planes [1]. It is a coupled hydro-mechanical problem, where equations for fluid flow and rock fracture propagation have to be solved simultaneously. The selection of an appropriate constitutive model, capable of representing the mechanical behavior in a realistic way, incorporating relevant rock properties, such as fracture energy, is a critical task in modeling of hydraulic fracturing.

In this paper, a strong discontinuity approach to embed discontinuities into finite elements [2] was implemented in a numerical code, which performs numerical analysis of fluid flow in a deformable reservoir. This technique is based on the decomposition of the displacement field, inside the element, into a component associated with the deformation of the continuum portion and a component related to the rigid-body relative motion between the two parts of the element. Moreover, the traction continuity condition must be imposed to ensure a correct relationship between the tractions on the internal interface and the stresses in the surrounding continuum portion. Hydro-geomechanical coupling was determined by a law that relates the variation of transmissivity as a function of the fracture aperture. The discontinuity path is placed inside the elements, irrespective of size and specific orientation of them. In addition, mesh refinement is not necessary to capture these discontinuities.

The resulting numerical code was used to model hydraulic fracture propagation through naturally fractured reservoirs with relatively coarse meshes in a reasonable computational time. Furthermore, the results provided an important insight into the mechanisms that generate micro seismicity that occurs during hydraulic fracture stimulation. The interpretation of micro seismicity based on geomechanical analysis gives a more realistic estimation of the stimulated reservoir volume (SRV), otherwise SRV can be overestimated.

REFERENCES

[1] Farzin Hamidi and AliMortazavi, *A new three dimensional approach to numerically model hydraulic fracturing process*, Journal of Petroleum Science and Engineering, Available online 3 January 2014.

[2] O.L. Manzoli, P.B. Shing, *A general technique to embed non-uniform discontinuities into standard solid finite elements*, Computer and Structures, 84, 742-757, 2006.