Coupled Hydro-Mechanical Analysis Of Fault Reactivation Using Embedded Strong Discontinuity Finite Elements

L.B.S. Beserra[a]*, O.L. Manzoli[b], and L.J.N. Guimarães[a]

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

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

ABSTRACT

Injection and production of fluids cause changes of pressure, temperature and saturation that affect the state of stress in oil reservoirs, resulting in porosity and permeability variations. It is therefore a coupled hydro-mechanical problem. The fault is in general understood as the slide between two sides of the formation across a friction contact. Sealing faults are structures of great importance for the hydrocarbon trapping in the generation and migration processes. Due to its low permeability, fluid flow in reservoir is not allowed through the fault as well as oil migration to other permeable zones of the geological formation is prevented. When reactivation occurs, the fault permeability is increased allowing the fluid flow through it, compromising the hydraulic integrity of the cap rocks that seal the reservoir, causing pressure and fluid loss.

A technique to embed displacement discontinuities into finite elements, as presented in [1], was implemented in CODE_BRIGHT (COupled DEformation BRIne Gas and Heat Transport), a finite element procedure that performs numerical analysis of fluid flow in a deformable reservoir crossed by a geological fault in a coupled manner. The 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 stress in the surrounding continuum portion.

The strong discontinuities approach has also been implemented for the hydraulic problem, incorporating the discontinuities of pore pressure field that occur due to a band with lower permeability than the surrounding porous medium (sealing fault). The discontinuity of the pore pressure field has been treated similarly to the displacement field for purely mechanical problems.

The hydro-mechanical coupling has been determined by a law that relates the variation of permeability as a function of the displacement jump. Numerical simulations have been carried out to evaluate the performance of the finite element formulation proposed. This approach has proved to be able to model the mechanism of fault sealing reactivation avoiding the pathological mesh-size dependence or undesired exceeding discretization observed in classical numerical implementations [2].

REFERENCES

[1] 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).

[2] C. Callari, F. Armero, *Finite element methods for the analysis of strong discontinuities in couple poro-plastic media*, Comput. Methods Appl. Mech. Engrg, **191**, 4371-4400, (2002).