Finite strains fully coupled analysis of a horizontal wellbore drilled through a porous rock formation

N. Spiezia*[†] , V. Salomoni[†], C. Majorana[†]

[†] Department of Civil, Environmental and Architectural Engineering (DICEA)
University of Padua
Via Marzolo 9, 35131 Padova, Italy
e-mail: *nicolo.spiezia@dicea.unipd.it

ABSTRACT

Wellbore instability, in particular in deep perforations, continues to be one of the major problem in the oil and gas industry, that can dramatically increase production costs. To prevent instabilities during perforation, wellbores are temporarily supported by drilling mud pressure. If instability occurs, the value of the mud pressure needs to be sufficiently high to prevent compressional failure, but it should also be lower than a critical value that would cause tensile failure and unintentional hydraulic fracturing. Predicting faithfully the stress distribution around a borehole, and moreover the yielding and failure zones, is a challenging but fundamental task, essential to estimate the correct mud pressure and hence to prevent instabilities and sand production. This study focuses on quantifying the pressure distribution, stress field, plastic zones and the eventual inception of localized deformations around a horizontal borehole drilled at great depth through a highly porous rock formation.

The perforation of a wellbore in a saturated porous material is a coupled problem, which involves deformations of the solid phase and simultaneous diffusion of the fluid phase [1,2]. A fully coupled finite element method is adopted [3], considering both material and geometric nonlinearity in the solid matrix, resulting in a so called ***u**-p* formulation [4]. The variation of porosity and permeability, as consequence of the finite deformations of the solid matrix, is taken into account. As revealed by experimental tests [5], depending on the loading path, highly porous rock are susceptible to different failure mechanism, mainly due to shear-induced dilation and shear-enhanced compaction. Hence, the model adopts an elasto-plastic constitutive law characterized by two yield surfaces, that is able to capture the different failure modes.

The simulations investigate the quasi-static transient phenomenon associated with the perforation, until the steady state condition is reached. The model describes the evolution of the stress and pressure distribution, and moreover the propagation of the plastic zones around the borehole, elucidating the factors that either prevent or enhance the failure of the hole and the band initiation. The work demonstrates the capability of the finite deformations coupled approach to simulate the whole process.

REFERENCES

[1] Preisig M. and Prévost J.H., "Fully coupled simulation of fluid injection into geomaterials with focus on nonlinear near-well behavior", *Int. J. Numer. Anal. Meth. Geomech.*, Vol. **36**, pp. 1023–1040, (2012).

[2] Rutqvist, J., et al. "Coupled multiphase fluid flow and wellbore stability analysis associated with gas production from oceanic hydrate-bearing sediments." *Journal of Petroleum Science and Engineering*, Vol. **92**, pp. 65-81, (2012).

[3] Macinia P., Mesinia E., Salomoni V.A., Schrefler B.A., "Casing influence while measuring in situ reservoir compaction", Journal of Petroleum Science and Engineering, Vol. **50**, pp. 40–54, (2006).

[4] Song X., and Borja R.I., "Mathematical framework for unsaturated flow in the finite deformation range." *International Journal for Numerical Methods in Engineering,* Vol. **97**, pp. 658-682, (2014).

[5] Cuss, R. J., Rutter, E. H., and Holloway, R. F., "Experimental observations of the mechanics of borehole failure in porous sandstone.", *International Journal of Rock Mechanics and Mining Sciences*, Vol. **40**, pp. 747-761, (2003).