International Journal of
Geohazards and Environment
http://ijge.camdemia.ca, ijge@camdemia.ca

IJGE 2016 2(1): 2-16
Available at http://ojs.library.dal.ca/ijge

In-Situ Stress Estimation by Back Analysis Based on Wellbore Deformation with Consideration of Pore Pressure

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Abstract: In oil and gas industry, wellbore stability control is paramount in an operation. It is essential to have information of the in situ stresses in well planning and prevention of wellbore failure. However, the current available measurement methods for in situ stresses in petroleum engineering are costly and often give scattering results. In this paper, a more practical displacement-based back analysis technique is proposed to determine the magnitude and orientation of the in situ stresses. The purpose is to provide an alternative tool for small operators in petroleum industry. An analytical solution is derived from displacement-stress relationship around a well in an isotropic rock with consideration of pore pressure. This method can be applied to calculate the displacement at any point around the well induced by drilling. In a reversed order, it can be used to calculate the in situ stresses from measured displacements at a number of locations on the borehole wall. For practical purpose, drained and undrained constitutive 2D models using measured diametrical deformation at different locations around a borehole wall as the input data have been developed to estimate the in situ stresses. Program codes in Matlab were written to facilitate the analysis under different conditions. An example is introduced to test the model and the program. The results validated this back-analysis approach and made a reliable estimation of the in situ stresses. The effects of pore pressure are also evaluated and are found to have significant impact on the shape of wellbore deformation. This impact differs for the drained and undrained conditions.

Keywords: in situ stresses, wellbore, back-analysis, diametrical deformation, constitutive model

1 Introduction

Underground formations are always in a stressed state due to the stresses in the ground, known as the in situ stresses resulted from the weight of the overlaying strata and the locked-in stresses of tectonic origin. Wells drilled into the rock mass are the only accesses developed to reach an oil and gas reservoir. The stability of a well is paramount to an operation. In situ stresses refer to the static stresses before drilling. Together with the pore pressure in the reservoir, they are among the key factors that affect the wellbore stability and play significant roles in well planning, drilling, wellbore stability control and hydraulic-fracturing application. Therefore getting reliable data of in situ stresses, particularly in the plane perpendicular to the well axis, is essential for the development of an oil and gas reservoir (Fjaer 2008, Sinha et al 2008, Kang et al 2009, Afsari et al 2010). At present, a number of methods are available for measuring or estimating the orientation and magnitude of the in situ stresses in petroleum engineering (Aadnøy and Looyeh 2011, Nauroy 2011). The stress state at a given point in the rock formation prior to drilling is generally presented in terms of the principal components: the vertical stress σ_v, the maximum horizontal stress σ_{hmax} and minimum horizontal stress σ_{hmin}. Normally the vertical stress can be obtained from rock density and depth.

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DOI: 10.15273/ijge.2016.01.002