Determination of Direction and Magnitude of in Situ Stresses by Borehole Breakout Method in an Oil well in the Southwest of Iran

Ali Reza Najibi[1], Mohammad Ghafoori[2*],
Gholam Reza Lashkaripour[3], Mohammad Reza Asef[4]
1, 2, 3. Geology Department, Ferdowsi University of Mashhad, Iran
4. Kharazmi University, Tehran, Iran

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Extended Abstract

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Introduction

Determination of in situ stress-direction and magnitude are prerequisite for any oil well drilling and oil field development such as hydraulic fracturing. One of the simplest and most widely used methods is called borehole breakout analysis. Breakouts are compression fractures made in the direction of minimum horizontal in situ stress (Sh), if drilling mud pressure be lower than optimum mud pressure. Some borehole imaging logs such as FMI, FMS and UBI are appropriate tools for wellbore fracture detection. These fractures are distinguished in the logs as dark and symmetrical points (or lines) on both sides of the well and are used as an indicator for in situ stress studies. The size and shape of these fractures are strongly depend on the magnitude of the in situ stress. Therefore, many researchers suggested that by analyzing the geometric shape of the borehole breakout is an appropriate technique for estimation of in situ stress components.

Material and Methods

Rock masses in the earth crust are affected by in situ stress in three components as a vertical (Sv) and two horizontal (SH and Sh). In isotropic and linear elastic coordinate, the principal stresses in (r, θ) coordinate in the wellbore are defined as

$$\sigma_r = \frac{1}{2}(S_H + S_h)\left(1 - \frac{R^2}{r^2}\right) + \frac{1}{2}(S_H - S_h)\left(1 - \frac{4R^2}{r^2} + \frac{3R^4}{r^4}\right)\cos 2\theta + \frac{\Delta P R^2}{r^2} \quad (1)$$

$$\sigma_\theta = \frac{1}{2}(S_H + S_h)\left(1 + \frac{R^2}{r^2}\right) - \frac{1}{2}(S_H - S_h)\left(1 + \frac{3R^4}{r^4}\right)\cos 2\theta - \frac{\Delta P R^2}{r^2} \quad (2)$$

$$\tau_{r\theta} = -\frac{1}{2}(S_H + S_h)\left(1 + \frac{2R^2}{r^2} - \frac{3R^4}{r^4}\right)\sin 2\theta \quad (3)$$

where σ_r, σ_θ and $\tau_{r\theta}$ are radial, circumferential and tangential shear stresses, respectively. Moreover, R is borehole radius, r is the distance to borehole centre, θ is azimuth measured from the direction of SH and ΔP, a difference between the fluid pressure in the borehole and that in the formation (positive indicates excess pressure in the borehole). According to Mohr-Coulomb failure criteria, the minimum and maximum horizontal stresses can be calculated using the following equations.

$$S'_h = 2\,\frac{(a_1+a_2)(C+f\Delta P)-(c_1+c_2)(C-e\Delta P)}{(a_1+a_2)(d_1+d_2)-(b_1+b_2)(c_1+c_2)} \quad (4)$$

$$S'_H = 2\,\frac{(d_1+d_2)(C-e\Delta P)-(b_1+b_2)(C-f\Delta P)}{(a_1+a_2)(d_1+d_2)-(b_1+b_2)(c_1+c_2)} \quad (5)$$

$$\frac{S'_H}{S'_h} = \frac{(d_1+d_2)(C-e\Delta P)-(b_1+b_2)(C-f\Delta P)}{(a_1+a_2)(C+f\Delta P)-(c_1+c_2)(C-e\Delta P)} \quad (6)$$

where

$$a_1 = -\mu(1 - 2\cos 2\theta_b)$$

$$a_2 = (1+\mu^2)^{\frac{1}{2}}(1 - 2\cos 2\theta_b)$$

$$b_1 = -\mu(1 + 2\cos 2\theta_b)$$

$$b_2 = (1+\mu^2)^{\frac{1}{2}}(1 + 2\cos 2\theta_b)$$

$$c_2 = (1+\mu^2)^{\frac{1}{2}}(1 - \frac{R^2}{r_b^2} + \frac{3R^4}{r_b^4})$$

$$d_1 = -\mu(1 - \frac{2R^2}{r_b^2})$$

$$d_2 = (1+\mu^2)^{\frac{1}{2}}(-1 + \frac{3R^2}{r_b^2} - \frac{3R^4}{r_b^4})$$

$$e = -(1+\mu^2)^{\frac{1}{2}}$$

$$f = -(1+\mu^2)^{\frac{1}{2}}\frac{R^2}{r_b^2}$$

where C and μ are cohesion and internal friction angle. It should be noted that the vertical in situ stress may be measured from the density (ρ) in the desired depth (h) according to the following well known equation

$$S_v = \int_0^Z \rho_{(Z)}\, g\, dZ \cong \rho \bar{g} Z \quad (7)$$

Results and Discussions

The well was drilled in Sarvak formation in diameter of 5.875 inches. However, some borehole breakout induced that recorded in image log tools. As the borehole breakouts extended parallel to the Sh, the fracture analysis in a rose diagram may show the in situ directions. As shown in the figure, the borehole breakouts in the study well are spread in strike / dip of 305/85. Hence, direction of Sh is parallel to the main Zagros thrust fault in N55W. Subsequently, SH is perpendicular to Sh in N35E and parallel to the Arabian plate motion to Iran. The in situ stress magnitudes in the study well is calculated using the Mohr – Coulomb failure criterion and density data using Equations 4, 5 and 7. The results indicated that the stress relations in the study well are SH > Sv > Sh. According to Anderson's fault theory, the tectonic regime in the well is strike slip.

Conclusions

In this research, direction and magnitude of in situ stresses determined in an oil well in the Ahwaz region by borehole breakout analysis. In this region, the direction of maximum horizontal in situ stress (SH) found to be N35E, infer to the direction of compression pressure from the Arabia plat to Iran. Also, direction of minimum horizontal in situ stress (Sh) is N55W parallel to Zagros thrust. Furthermore, the magnitude of vertical in situ stress (SV) is lower than SH and higher than Sh (SH>SV>Sh) indicates to strike-slip tectonic regime. Knowing of direction and magnitude of in situ stress led to the estimation of optimum mud pressure and selection of proper drilling path in directional oil wells.

Keywords: In situ stress, Borehole Breakout, Geomechanics, Fracture, Ahwaz

*Corresponding Author: ghafoori@um.ac.ir