UR36

How Geomechanics Analysis Help to Improve Hydraulic Fracture Design in Organic Shales

C. Trejo* (Schlumberger)

Summary

The laminations in the organic shales influence the hydraulic fracture height because of the difference in mechanical properties measured normal and parallel to the bedding planes. Organic shales are considered as anisotropic media. Run sonic logs and generate the stress profile from these logs is a good practice to account the difference in mechanical properties in the vertical and horizontal direction (anisotropy).
Geomechanics analysis help to better understand the hydraulic fracture geometry for the stimulated volume in unconventional resources.

Introduction

There are significant differences between the evaluation of unconventional resources and conventional plays. The exploitation of unconventional reservoirs requires large hydraulic fracture stimulations that contact a huge reservoir surface area and effectively connect this surface area back to the wellbore. Contacting a large reservoir surface area significantly increases hydrocarbon production rates and recovery, enabling economic development. In fact, the effectiveness of the hydraulic fracture treatment will control both well productivity and drainage area in unconventional reservoirs (Cipolla et al. 2008).

The laminations in the organic shales influence the hydraulic fracture height because of the difference in mechanical properties measured normal and parallel to the bedding planes. Organic shales are considered as anisotropic media. Run sonic logs and generate the stress profile from these logs is a good practice to account the difference in mechanical properties in the vertical and horizontal direction (anisotropy).

Ignoring the impact of mechanical property anisotropy can lead to significant errors in the estimation of hydraulic fracture height. The optimal landing point of a horizontal wellbore may not be selected when ignoring this effect. This can result in excessively high fracture initiation pressures, difficulty achieving injection rate, and unexpected fracture height growth. Each of these factors can result in un-optimized productivity.

Anisotropy in mechanical properties

If the shale laminations are horizontal and the formation has no dip, the formations is defined as transverse isotropic with a vertical axis of symmetry (TIV). The sonic velocities measured in the two vertical orthogonal directions are assumed equal. They are different from the horizontal velocity measured parallel to the laminations, Figure 1.

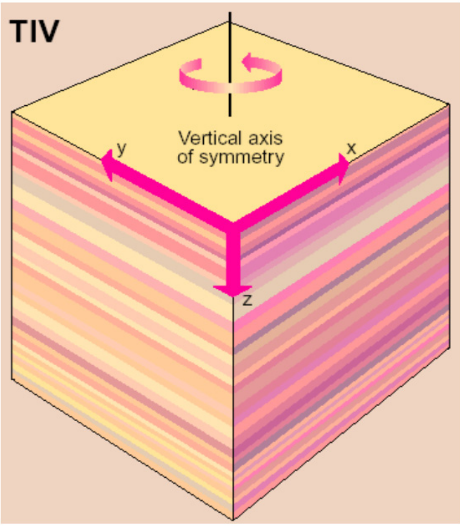

Figure 1 *TIV anisotropy- the sonic velocities measured in the two vertical orthogonal directions are assumed equal. They are different from the horizontal velocity measured parallel to the laminations.*

Minimum horizontal stress

Equation 1 presents the traditional equation used to determine the minimum horizontal stress for an isotropic medium that is believed to be linear elastic:

$$\sigma_{Hmin} = \frac{\mu}{1-\mu}(\sigma_v - \alpha p_p) + \alpha p_p + \frac{E}{1-\mu^2}\epsilon_{H_{max}} + \frac{E\mu}{1-\mu^2}\epsilon_{H_{min}}$$ ……………………………(1)

where:

σHmin= Minimum horizontal stress gradient (psi/ ft)
μ= Poisson's ratio
σv= Overburden stress gradient (psi/ ft)
pp= Pore pressure gradient (psi/ft)
α= Biot's elastic constant
E= Young's modulus (psi)
ϵ_{Hmax}= Maximum horizontal strain
ϵ_{Hmin}= Maximum horizontal strain

Variants of this equation are the foundation for calculating stress with advanced acoustic logs. Equation 2 is used to determine the minimum horizontal stress for TIV medium (Thiercelin and Plumb 1994).

$$\sigma_{Hmin} = \frac{E_h}{E_v}\frac{\mu_v}{1-\mu_h}[\sigma_v - \alpha(1-\xi)p_p] + \alpha p_p + \frac{E_h}{1-\mu_h^2}\epsilon_{H_{max}} + \frac{E_h\mu_h}{1-\mu_h^2}\epsilon_{H_{min}}$$ ………………….(2)

where:

Eh= Horizontal Young's modulus (psi)
Eh= Vertical Young's modulus (psi)
μh= Horizontal Poisson's ratio
μv= Vertical Poisson's ratio
ξ =Poroelastic constant

Conclusions

- Shale reservoirs are laminated and these laminations create anisotropy
- In-situ stress tests indicate that an anisotropic stress model provides a more accurate prediction of minimum horizontal stress than an isotropic model that ignores this mechanical properties variability.
- Geomechanics analysis is important to predict the hydraulic fracture geometry

References

George A. Waters, Richard E. Lewis and Doug C. Bentley (2011) The effect of mechanical properties anisotropy in the generation of hydraulic fractures in organic shales. SPE 146776.

George Waters and Ruhao Zhao (2011) Measuring the impact of geomechanical heterogeneity in organic shales on hydraulic fracture initiation and propagation. SPE 147597.