JOURNAL OF PETROLEUM GEOMECHANICS
(JPG)

Extended Abstract

Theoretical and Conceptual Investigation of the Effect of Pore Water Chemistry on Formation Breakdown Pressure Estimation using Conventional Models in Hydraulic Fracturing Operation

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Received: 15 April 2023; Accepted: 29 May 2023

DOI: 10.22107/JPG.2023.387350.1193

Keywords

Pore Water Chemistry,
Formation Breakdown Pressure,
Hydraulic Fracturing,
Disjoining pressure

Abstract

The P_B can be estimated based on different theoretical and empirical models. However, in these models, the geochemical effect is not directly captured. Besides, the accuracy of P_B estimation using these relations is still unknown. In this study, the accuracy of P_B estimation using the conventional models and the effects of pore water chemistry on P_B were investigated using published data from literature. Also, a new model was developed based on the concept of effective stress, disjoining pressure and the superposition principle for stress distribution around well-bore. The results indicate that most of the conventional models are unsuccessful in P_B prediction for hydraulic fracturing operations. As an example, the popular Hubert-Willis model has an average error of 34.7%. Our study indicates that pore water chemistry has a substantial effect on rock wettability and P_B due to the change of intergranular forces, based on the DLVO theory, affecting the rock strength.

1. Introduction

In different locations of reservoir with the same rock type under the same regional stress conditions, the breakdown process depends on the pore fluid properties and rock-fluid interactions. Based on our study conducted on one of the Asmari reservoirs in Iran, the chemical composition of formation water samples from 39 wells vary greatly in different locations. As an example, sulfate ion has an variation in the range of 100 to 2750 ppm. In relation to HF, rock-fluid geochemical interaction can affect geomechanical properties as a “static” factor, and on the fluid flow as a “dynamic” factor. Therefore, due to the different pore water conditions of a reservoir rock, the design of this operation can be different.

2. Methodology and Results

2.1. Conventional Models of P_B Estimation

Based on statistical criteria, eleven conventional models were considered with 168 field and laboratory data, taken from the published literature [1]. According to the final ranking of these models, it can be concluded that the Aadnoy-Belayneh 1 2008 model is relatively more reliable for use in the design of HF operations. This model estimates the P_B with an average error of 29.4%. Also, the common Hubert-Willis model has an average error of 34.7%. This large error may indicate the influence of the regional water chemistry in estimating P_B.

2.2 Effect of Pore Water Chemistry

Most researchers have rejected the capillary effects [2]. Some research works also show that the dissolution of rock by pore water or seawater is negligible [3]. Based on reference [4], increasing the sulfate ion concentration in the pore water makes the rock more water-wet and the strength of the rock decreases. However, according to reference [5], increasing sulfate ion concentration, the rock strength is enhanced. Thus the published results are contradictory. The wettability state of reservoir rock is attributed to the interlayer forces [6]. The consequence of these interlayer forces is expressed by disjoining

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pressure (P_D). The electric charge of the grains surface not only may affect the wettability of the rock, but also it can create an electrostatic repulsion in vicinity of the contact surface of grains and affect the strength of the rock. However, the mechanism that is common in terms of strength and wettability is the magnitude of the interlayer forces. When an oil phase is present in the contact surface of two grains, it weakens the effect of electrostatic force [4], [3] (Figure (1)). (A) is stronger than (B).

2.3. Inclusion of P_D in the poroelastic system

If a cross-section of a rock with the total area (A_T) and the total applied stress on it (σ) is assumed, it can be seen that the stresses acting on individual grains result from the difference between the applied normal stresses and fluid pressure [7]:

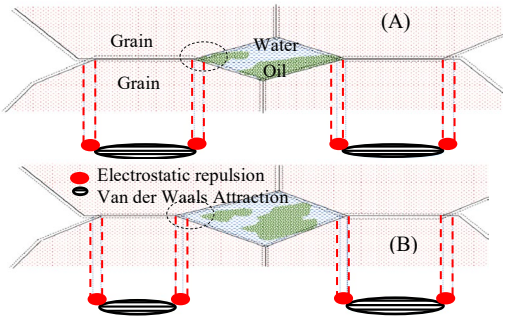

Fig. 1. Different phase placement.

$$\sigma A_T = \sigma_C A_C + P_P(A_T - A_C) \quad (1)$$

where σ_c is the effective normal stress acting on the grain contact. Now we introduce the parameter λ as $\frac{A_C}{A_T}$. By the limiting operation where λ is approached to zero, the "effective" stress applied on individual grains, σ_g, is:

$$\sigma_g = \sigma - (1 - \lambda)P_P \quad (2)$$

In the grain contact surface and assuming partial contact and the presence of a water film, the stress resulting from this fluid is:

$$\lim_{\lambda \to 0} \lambda P_P = P_D \quad (3)$$

This pressure tends to zero with distance from the grain surface. Therefore, the amount of "effective" stress on individual grains, σ_g:

$$\sigma_g = \sigma - P_P + ZP_D \quad (4)$$

where Z represents the sign of P_D. Applying the principle of superposition, P_D can be incorporated to the tangential effective normal stress $\sigma_{\theta\theta}$. Consequently, P_B can be predicted in different geochemical conditions. For example, the Haimson-Fairhurst (H-F) model can be:

$$P_b = \frac{\sigma_T + 3\sigma_3 - \sigma_1 - \eta P_P + ZP_D}{2 - \eta} \quad (5)$$

Using Israelachvili (2011) equations [5] and [4], the P_D values for charged surfaces can be calculated. The P_B of our model (Chalkstone[4]) was calculated for two models of H-F and modified H-F (Figure (2)). Based on this figure, with the increase in sodium sulfate concentration, the P_B decreases. Further increase of sulfate ion concentration can cause the surface charge of the grains to become more negative.

3. Conclusions

- There is a high risk in using most of the conventional models for estimation of P_B, with an average error of 30% .
- The modified model incorporating disjoining pressure can leads to more accurate estimation of P_B. By assuming a pore water consisting of Na^+ and SO_4^{-2} ions and a chalk rock, our results show that by increasing sulfate ion concentration, the P_B decreases or the rock becomes weaker.
- This model is also of application for estimation of PB where injected water has a lower salinity than formation water (EOR).

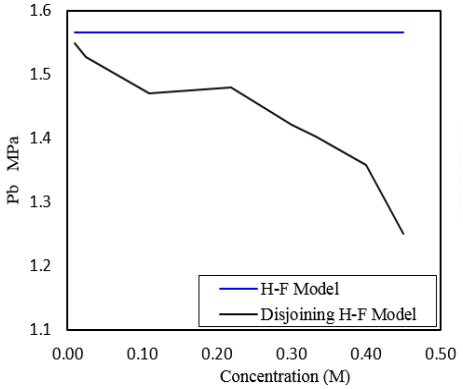

Fig. 2. Estimated P_B values using H-F and modified H-F models at different concentraitons of Na_2SO_4

4. References

[1] Kiss A, Fruhwirth R., Pongratz R., Maerr R. (2018): PB Prediction with Artificial Neural Networks. SPE-191391-Oct. Muscat.

[2] Bergsaker, Røyne, Ougier, Renard, (2016): The effect of fluid composition, salinity, and

acidity on subcritical crack growth in calcite crystals. J. Geoph. Res.: V. 121, P.: 1631–1651.
[3] Sachdeva, Nermoen, Reidar, Korsnes, Madland, (2020): Effect of Initial Wettability on Rock Mechanics and Oil Recovery. Transport in Porous Media, Vol. 133, P: 85-117.
[4] Megawati M., Hiorth A., Madland M. V., (2013): The impact of surface charge on the mechanical behavior of high-porosity chalk. Rock Mech. Rock Eng. Vol. 46, Iss. 5, P.:1073–1090.
[5] Strand, S., Høgnesen, E.J., Austad, T., (2006b): Wettability Alteration of Carbonates Effects of Potential Determining Ions (Ca^{2+} and SO_4^{2-}) and Temperature. Colloids and Surfaces A: Physicoch. & Eng. Aspects, V. 275, P.: 1-10.
[6] Israelachvili J, (2011): Intermolecular and surface forces. Academic Press, New York City.
[7] Zoback M., (2010-2007): Reservoir Geomechanics. ISBN-978-0-521-77069-9. P. 65-69.