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Prediction of Skin Factor Reduction and Production Enhancement of Gas Well in The Field based on Core-Novel Stimulation Chemical Compatibility Test in Laboratory

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Abstract. The article is focused on studying the condition of the physical properties of the reservoir rock before and after being injected with HPWBM (High Performance Water-Based Mud) and stimulated by Novel Chemical refers to the core compatibility test in the laboratory. Hereafter, calculations are carried out to predict the estimated skin factor reduction and production enhancement of gas well in the field based on the laboratory results. The next step is testing liquid permeability using KCL, this test is carried out before and after HPWBM injection and novel chemical injection. Therefore, the physical properties of the core were obtained before and after HPWBM and novel chemical treatment. Based on the core permeability value, the skin factor calculation was performed after HPWBM invasion and after injection of novel chemical with Tarek Ahmed (2001) equation, then nodal analysis was calculated to predict the increase in gas well production rate after treatment with novel chemical. The results of core permeability after being injected with HPWBM filtrate was decreased from 8.56 mD to 1.56 mD, which indicates that the invasion of the mud filtrate can cause damage in the borehole, then the core permeability after being injected with novel chemical shows an increase from 1.56 mD to 3.79 mD, this proves that novel chemical is able to reduce damage to rocks. Based on estimation of the skin calculations and well production rate results, it is shown that the novel chemical is predicted to be able to reduce gas well skins caused by HPWBM filtrate by reducing skin by 72% and able to produce with an estimated gas flow rate of 1.2 MMscfd.

Keyword(s): Stimulation Chemical; Core Compatibility Test; Skin Factor; Production Enhancement.

1 Introduction

Formation damage refers to the impairment of physical, chemical or mechanical properties of petroleum-bearing formation, which primarily involves permeability damage during various processes of oil and gas recovery (Yuan and Wood, 2018); more usually, it reduces the efficiency of secondary and tertiary recovery from reservoir and impairs well injectivity and/or productivity dramatically (Bedrikovetsky, 1993). Interactions of reservoir with drilling and completion fluids, mud cake and mud filtration, lead to near wellbore damages due to plugging the pores with solid particles, which result in reduction of production rate (Vakilinia, 2012). Formation damage can be quantitatively described in terms of skin factor.

Problems related to skin have been found caused by High Performance Water-Based Mud (HPWBM) in Gas Well at PT Pertamina Hulu Sanga Sanga Field. To validate and analyze the causes of these problems, a compatibility test was carried out on the core of from those Gas Well, so that it could be seen the effect the core that had been invaded by HPWBM and the effect of novel chemical in stimulating the HPWBM-infected core, and it is expected that the results of the core compatibility test can provide information related to the condition of the physical properties of the reservoir rock before and after injection with HPWBM and novel chemical as well as predict the estimated reduction in "skin factor" and increase in gas well production in the Gas Well based on the results of core compatibility test.

2 Methods

Regarding the steps of the core compatibility test scheme as referred to in Figure 1, the test is carried out before and after HPWBM injection and novel chemical injection. Then the physical properties of the plug core rock were obtained before and after HPWBM and novel chemical treatment. Based on the core permeability value, the skin factor calculation was performed after HPWBM invasion and after injection of novel chemical with Tarek Ahmed (2001) equation, then nodal analysis was calculated to predict the increase in gas well production rate after treatment with novel chemical.

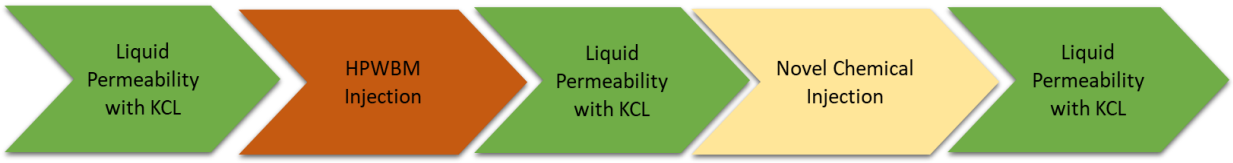

Figure 1. Core Compatibility Test Scheme on Sample Core of Gas Well

This novel chemical consists of two chemicals, the first chemical is acidic and non-corrosive with a low pH (around 1-2) and a specific gravity (SG) of around 1.1, it is a water based and surfactant with broad applications such as removing scale, wax, filter cake and cleaning accumulated clay. while the second chemical is an alkaline additive with a pH of around 12.5 and an SG of around 1.31 and does not cause damage to formations and wells. this chemical can dissolve barite, carbonate, magnesium, strontium, calcium, and barium sulfate which can dissolve drilling materials such as "lost circulation material"

3 Results

The data on the results of the liquid permeability test of core sample from Gas Well at PT Pertamina Hulu Sanga Sanga Field as referred to in Table 1. Based on Table 1, it is known that the core permeability (k) is 8.56 mD before HPWBM injection, the core permeability (k_{skin}) is 1.56 mD after HPWBM invasion, and the core permeability (k) is 3.79 Md after novel chemical injection. This shows that HPWBM can decrease core permeability by about 82%, and stimulation with Novel Chemical can increase core permeability by twofold.

Table 1. Test Results of Core Permeability.

Test Conditions	***Liquid Permeability* with KCL (mD)**
Before HPWBM Injection	8.56
After HPWBM Injection	1.56
After Novel Chemical Injection	3.79

3.1 Core Skin Factor Estimation

To estimate the Skin Factor by referring to the data from laboratory tests, the formula in equation (1) is used as follows (Tarek Ahmed, 2001):

$$s = \left[\frac{k}{k_{skin}} - 1\right] ln\left(\frac{r_{skin}}{r_w}\right) \quad (1)$$

Where:
k = formation permeability/core (mD)
k_{skin} = permeability of skin zone, (mD)
r_{skin} = skin radius (ft)
r_w = drill hole radius (ft)

For simplification of calculations, the parameters r_{skin} and r_w will be ignored by considering the condition of the core as a finite element. So, for the calculation of the skin factor core after HPWBM invaded according to equation (1) as follows:

$$s = \left[\frac{8.56}{1.56} - 1\right] = 4.49$$

As for the calculation of the Skin Factor core after being injected with novel chemical, according to equation (1) as follows:

$$s = \left[\frac{8.56}{3.79} - 1\right] = 1.26$$

The decrease in skin factor after chemical injection from HPWBM is estimated by equation (2) as follows:

$$Percentage\ decrease\ of\ skin\ factor\ (\%) = \frac{skin\ (A) - skin\ (B)}{skin\ (A)} \times 100\% \quad (2)$$

Where:
A = condition after HPWBM invasion
B = condition after novel chemical injection

As for the calculation of decrease in skin factor after chemical injection from HPWBM, according to equation (2) as follows:

$$Percentage\ decrease\ of\ skin\ factor\ (\%) = \frac{4.49 - 1.26}{4.49} \times 100\% = 72\%$$

3.2 Skin Factor and Production Rate Prediction of Gas Well

It is known from the field that the skin factor value of the Gas Well after mud invasion is 45 and the production rate is 0 MMscfd (no flow), and sensitivity nodal analysis of gas production has been carried out for various skin factor values as referred to in Figure 2 below:

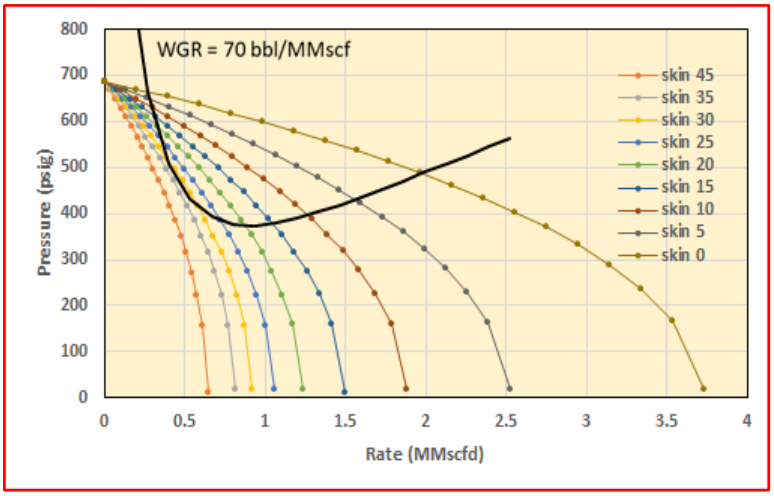

Figure 2. Nodal Analysis – Sensitivity of Gas Well Skin Factor the Flow Rate (PHSS, 2021)

Based on the percentage decrease of skin factor after chemical injection, which is 72% and it is assumed to be the same for the percentage decrease of skin factor for the Gas well, the estimated skin factor value for the Gas Well after chemical injection using equation (3) is as follows:

$$Skin\ after\ chemical\ injection = Skin\ (A) - \left(\frac{Percentage\ (B)}{100\%} \times Skin\ (A)\right) \quad (3)$$

Where:
Skin (A) = skin after mud invasion
Percentage (B) = percentage decrease of skin factor

As for the calculation of skin after chemical injection, according to equation (3) as follows:

$$Skin\ after\ chemical\ injection = 45 - \left(\frac{72\%}{100\%} \times 45\right) = 12.6$$

So, with reference to the sensitivity of the nodal analysis above, the skin factor of the Gas Well is 45 and the gas production rate is 0 MMscfd, then after chemical injection the skin value will decrease to 12.6 and the gas production rate is estimated to increase to around 1.2 MMscfd as referred to in Figure 4 below. Based on the results of skin calculations and well production rate estimates, it is shown that the novel chemical is predicted to be able to reduce gas well skins caused by HPWBM filtrate by reducing skin by 72% and can reactivate gas wells that were previously not producing (0 MMscfd) to be able to produce with an estimated gas flow rate of 1.2 MMscfd.

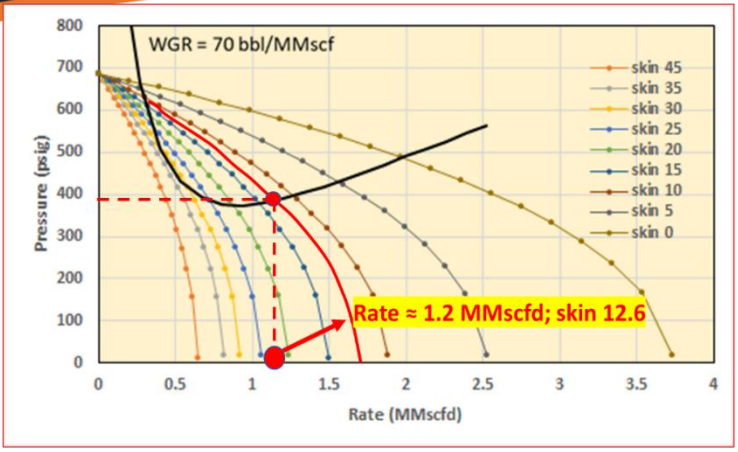

Figure 3. Estimation of Gas Well Flow Rate with 12.6 Skin Factor

4 Conclusions

Based on the results obtained in this study the following conclusions can be drawn.

1. This study has demonstrated the successful application of Novel Chemical to reduce formation damage caused by the invasion of High Performance Water-Based Mud (HPWBM) on a laboratory scale.
2. Novel Chemical can reduce the well skin caused by HPWBM with an estimated skin reduction of 72% (from 45 to 12.6) and can reactivate the Gas Well at the PHSS Field which was previously not producing (0 MMscfd) to be able to produce at an estimated gas flow rate of 1.2 MMscfd.

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