Premium Treatment System for Granite and Sandstone Formations – Fluid Development and Field Trial in a Geothermal Well

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ABSTRACT

Challenges encountered in the geothermal sector are versatile, continuously changing and increasingly demanding. Therefore, a customized approach for production enhancing treatments is recommendable. According to actual project demands, each treatment fluid system should especially be designed. At the same time, the ever-growing claim for products with the lowest possible environmental impact dramatically influences possible recipe compositions.

1. INTRODUCTION

The primary objective of acidizing geothermal wells in fractured sandstones and granites is to remove scales blocking the pathway of water, thus increasing the productivity or injectivity of the formation. For this purpose, hydrochloric acid- based fluids are commonly applied. At high temperature, however, the fierce reactivity of hydrochloric acid (HCl) often hinders deep penetration of the formation making stimulation of removed damaged zones difficult to attain (Lund et al. 1973, Lund et al. 1975). Selection of chemicals to reduce reactivity adds to the difficulties encountered in the acceptance by mining and water authorities.

Furthermore, the extreme corrosion tendency of hydrochloric acid requires high concentrations of corrosion inhibitors and intensifiers (Kalfayan 2008, Al-Mutairi 2005). Another problem often encountered during acidizing sandstones with HCl-based formulations is their incompatibility with clay minerals. Core flood experiments and field results indicate that high temperature illitic sandstone is sensitive to conventional mud acid (HCl/HF combinations) treatments. Here, the commonly employed HCl pre-flush degrades illite and chlorite leading to fines migration and formation damage (Thomas 2001).

This paper introduces an innovative fluid, which is based upon a naturally retarded, biodegradable acid system and highlights its first field trial in a granite formation. Here, demanding borehole conditions (195°C BHT, vast open-hole section, and a high concentration of illite) were encountered.

2. LAB EXPERIMENTS

Solubility tests were performed with actual cutting samples from the target zone at 80°C. After an exposure time of 3 hours in the respective biodegradable fluid system, the weight loss of the material was gravimetrically determined.

To simulate natural fractures in the formation and ensure an easy pathway for fluids, a granite core specimen was cut in half employing a core saw. Subsequent flooding experiments were conducted with a permeability tester at 140°C. Initial and final permeability was established by pumping a solution of 50 kg/m³ NH_4Cl at 1.6 mL/min for the sandstone core and 4.0 mL/min for the granite core. While applying a confining pressure (CP) of 2,000 psi and a back pressure (BP) of 500 psi, the respective biodegradable acid systems was pumped through the specimen.

Metal coupons were cut, polished and rinsed using butyl glycol prior to corrosion testing. Weight loss of the metal sample was determined after an exposure time of 3 hours in SSB-007 at 175°C. All tests were performed at a differential pressure of 1,000 psi N_2. Here, the fluid volume / metal surface area ratio was held constant at 5.7 mL/cm².

3. LAB RESULTS

Table 1 summarizes the results of solubility testing with cutting samples from the three target zones. In this context, SSB-007 dissolves mainly carbonates, whereas SFB-007 also targets silicates in granite and sandstone formations.

Table 1: Solubility of cutting samples from target zones, as determined after 3 hours at 80°C.

Sample	Solubility in SSB-007, %	Solubility in SFB-007, %
1	8	23
2	9	25
3	14	28

Flooding experiments with actual core specimen confirm these findings (see Figure 1 and 2). By pumping the innovative biodegradable treatment fluids SSB-007 and SFB-007, core permeability increases from approximately 1 to 10 mD for the sandstone specimen and from 4 to 139 mD for the granite core.

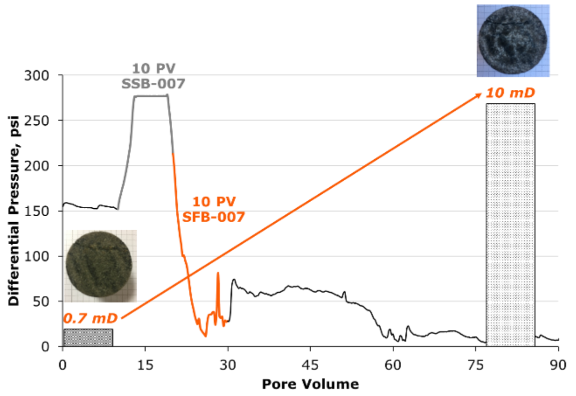

Figure 1: Flooding with sandstone core at 2,000 psi CP, 500 psi BP, and 140°C.

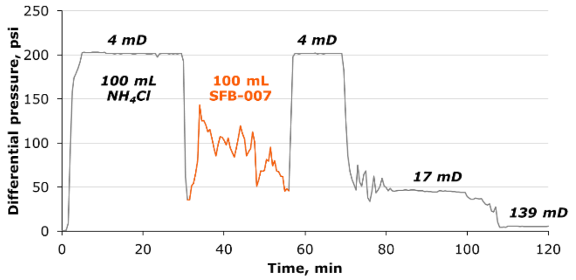

Figure 2: Flooding with granite core at 2,000 psi CP, 500 psi BP, and 140°C.

Figure 3: Granite core before and after flooding experiments.

As shown by Figure 3, SFB-007 effectively targets the clay mineral illite, without generating fines formation. Corrosion testing revealed an extremely low corrosivity for the biodegradable acid system of 0.003 lbs/ft² (see Figure 4; threshold: 0.05 lbs/ft²).

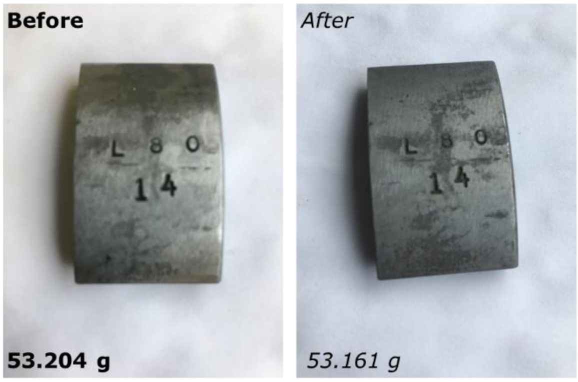

Figure 4: L-80 metal coupon before and after exposure to SSB-007.

4. FIELD TRIAL

For the first field trial, three target zones (MD: 4900 – 5300 m) in the open-hole section were selected for chemical injection via tubing. Figure 5 shows equipment on site and the respective pumping schedule for each treatment. The superior chemical properties of the innovative acid systems SSB-007 and SFB-007 lead to a greatly enhanced injectivity of the well (see Figure 6).

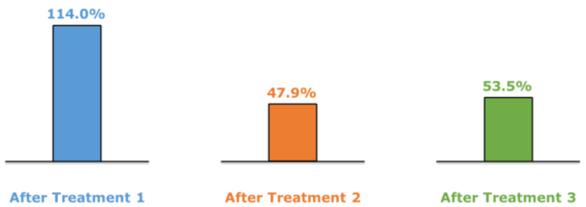

Figure 6: Improvement according to casing pressure during injection tests.

5. CONCLUSIONS

Based upon excessive lab testing and vast field experience, the biodegradable acid systems presented here were specifically customized to meet unique project-related demands. In the course of numerous applications, they have shown their excellent efficiency improving the productivity of geothermal wells. Their biodegradability, low corrosion tendency and excellent compatibility profile complement these state-of-the-art treatment fluids.

Step	Treatment 1	Treatment 2	Treatment 3
Pressure test	100 bar	200 bar	250 bar
Pumping FW	10 m³	20 m³	120 m³
Mixing of chemicals	6 hours	6 hours	6 hours
Rig-pumping FW	120 m³	120 m³	120 m³
Pumping SSB-007	35 m³	55 m³	60 m³
Pumping SFB-007	35 m³	55 m³	60 m³
FES-pumping FW	55 m³ (tubing)	55 m³ (tubing)	55 m³ (tubing)
Rig-pumping FW	70 m³ (annulus)	110 m³ (annulus)	120 m³ (annulus)
Reaction time	3 hours	3 hours	3 hours

Figure 5: Equipment on site and pumping schedule.

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