GeoTHERM
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Tiefe Geothermie

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Ortenauhalle Congress 1
Deep geothermal energy

Viscosified System for Enhanced Acidizing of Geothermal Wells in Sandstone Formations

Tensid-basiertes System zur verbesserten Säurebehandlung von Geothermiebohrungen in Sandsteinformationen

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In geothermal projects, the main goal of acidizing injector wells in sandstones is scale removal and consequently injectivity increase. At low temperature, hydrochloric-based treatment fluids are commonly employed for this purpose. In this context, employing diverting agents to prevent acids from leaking into the most permeable sub-layer of the target zone is recommendable.

This paper presents the surfactant-based product SDA-550 which shows a tendency of forming rodlike micelles in acidic solutions. As shown in Figure 1, a chaotic worm-like arrangement of dissolved molecules leads to an increase in viscosity. This behavior creates a temporary blocking effect which causes fluid diversion and facilitates successful acidizing.

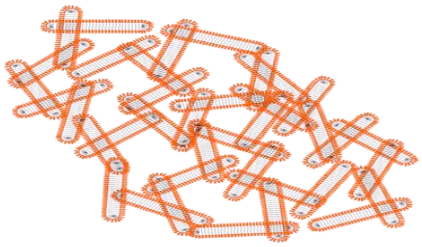

Figure 1: Macro-structure of surfactant-based product SDA-550 in acidic solutions.

Preparing the first field trial in a Dutch geothermal well, we performed extensive lab experiments regarding solubility of solid samples, corrosion of metal coupons, and rheology of acidic recipes containing different concentrations of SDA-550. The following table sums up the results of solubility testing with actual bailer samples from the well:

Fluid	Composition
1	15% Hydrochloric Acid
2	15% Hydrochloric Acid + 25 kg/m³ SCC-240

Test Parameter			
Temperature, °C	Δp N_2, psi	Exposure Time, hours	Fluid Volume, mL
40	Atm.	2	50

Test Results			
Weight before, g	Weight after, g	Weight Loss, g	Solubility, %
1.003	0.498	0.505	50
1.004	0.277	0.727	72

As shown in Figure 2, the dosage of corrosion inhibitor added to the acidic systems suffices to protect L-80 metal coupons.

Fluid	Composition
1	15% Hydrochloric Acid + 10 L/m³ SCI-123
2	15% Hydrochloric Acid + 25 kg/m³ SCC-240 + 10 L/m³ SCI-123

Test Parameter			
Temperature, °C	Δp N_2, psi	Test Time @ 75°C, hours	Test Time @ 40°C, hours
75 / 40	1,000	7	14

After 7 hours @ 75°C in Fluid 1		After 7 hours @ 75°C in Fluid 2	
Weight Loss, %	Material Loss, lbs./ft²	Weight Loss, %	Material Loss, lbs./ft²
0.028	0.001	0.032	0.001

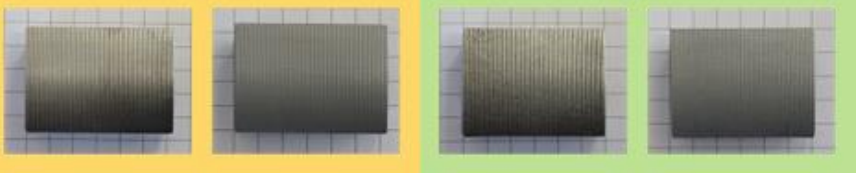

Figure 2: Results of corrosion testing with two different acidic recipes and L-80 coupons, as determined after 7 hours at 75°C.

For dissolving carbonates, as well as silicates in the Slochteren sandstone formation (BHST at approximately 75°C), HCl- and HCl/HF-based recipes were pumped in a stepwise approach (see table below). The addition of SDA-550 and hence the viscosity of the diverter step was adjusted based upon lab experience and in accordance with the client.

Step		Volume
1	15% Hydrochloric Acid	10 m³
2	5% Hydrochloric Acid + SDA-550 (viscosified Fluid)	4 m³
3	15% Hydrochloric Acid	6 m³
4	15% Hydrochloric Acid + 25 kg/m³ SCC-240	15 m³
5	5% Hydrochloric Acid	5 m³
6	Displacement 1 with Formation Water	91 m³
7	Displacement 2 with Formation Water	20 m³
8	Displacement 3 with Formation Water	15 m³
9	Reaction Time	0 m³
10	Injection Test	198 m³

The subsequent injection test with brine revealed a significant improvement in injectivity of the formation. While keeping the well head pressure at a constant level, we could increase the pumping rate by a factor of four.

Figure 3 summarizes the pumping schedule and Figure 4 shows equipment on site.

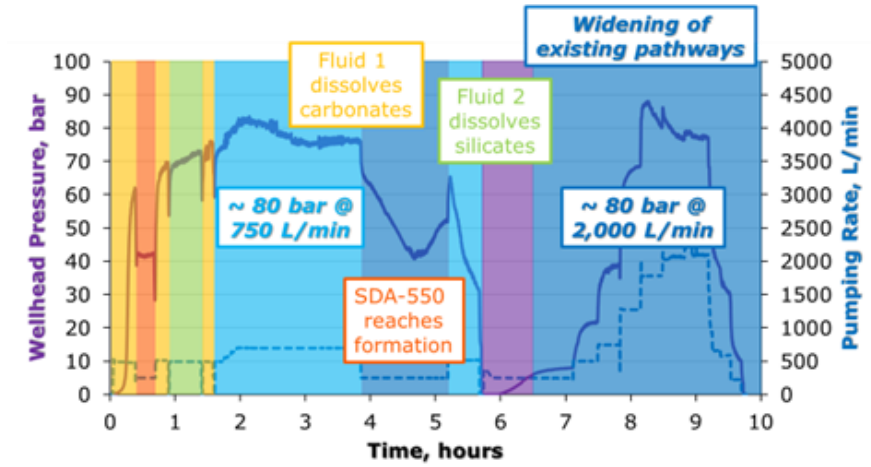

Figure 3: Pumping schedule.

Figure 4: Equipment on site.

This great result was achieved due to the superior chemical properties of our innovative diverter agent combined with the great effectiveness of the tailor-made treatment fluids. Thus, laboratory and field results impressively proof that we have reached the next level of acidizing sandstones..