SPE 138434

An Evaluation of the Impact of Reactive Perforating Charges on Acid Wormholing in Carbonates

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Agenda

Background

Objectives

Experimental Procedure and Parameters

Results

Conclusions and Recommendations
Background

CT Scan images of acidized cores (Bartko et al. 2007. SPE 105022)

Static Underbalanced $P_{inj}=3600$ psi
Dynamic Underbalanced $P_{inj}=2700$ psi
Gas-filled Wellbore Balanced $P_{inj}=2500$ psi
Acid-filled Wellbore Dynamic Underbalanced $P_{inj}=90$ psi
Perforation Geometry
Background

Conventional 25g

Reactive 25g
Background

Advantages:

• Improve injectivity and flow performance.

• Enhance stimulation job’s efficiency.

• Increase productivity to a point that would offset cost.

SPE116226, SPE122174,
SPE125901, SPE144167, SPE149453
Objectives

• Perforate a set of carbonate cores using conventional and reactive charges.

• Evaluate the geometry of reactive charges in carbonate rocks.

• Evaluate the effect of reactive charges on acid wormholing.
Experimental Procedure and Parameters

Simulated Wellbore → Simulated Casing → Pressure Transducers

Gun → Core Sample → Rubber Sleeve

Cement Plate

28-30 November, 2011  Middle East and North Africa Perforating Symposium

GEODynamics  Reactive Perforating and Acid Wormholing in Carbonates
Experimental Procedure and Parameters

Tip of Perforation

Inlet of Perforation

High Density

Clean Section
Experimental Procedure and Parameters
Experimental Procedure and Parameters

Syringe Pump

Back Pressure Regulators

Hand Pump (Overburden Pressure)

Oil

Acid

Pressure Transducers (Δp)

Data Acquisition System

Automatic Fluid Sample Collector

GEODynamics Reactive Perforating and Acid Wormholing in Carbonates
28-30 November, 2011 Middle East and North Africa Perforating Symposium
Experimental Procedure and Parameters

Steady State Flow

Acid Breakthrough

Acid Injection Starts
Experimental Procedure and Parameters
Initial Experiments

Acid flowed through the fracture

Fractures
## Initial Experiments Results

### 15 gram Charges

<table>
<thead>
<tr>
<th>Shot Type</th>
<th>Injection ΔP, psi</th>
<th>Acid to Break through, ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>274.00</td>
<td>66.67</td>
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<tr>
<td>Reactive</td>
<td>327.00</td>
<td>58.23</td>
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<tr>
<td>Conventional</td>
<td>321.50</td>
<td>41.67</td>
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<tr>
<td>Reactive</td>
<td>660.00</td>
<td>101.67</td>
</tr>
<tr>
<td>Conventional</td>
<td>206.00</td>
<td>62.5</td>
</tr>
</tbody>
</table>

### 7 gram Charges

<table>
<thead>
<tr>
<th>Shot Type</th>
<th>Injection ΔP, psi</th>
<th>Acid to Break through, ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>406.00</td>
<td>65</td>
</tr>
<tr>
<td>Reactive</td>
<td>371.00</td>
<td>60</td>
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<tr>
<td>Conventional</td>
<td>421.00</td>
<td>64.17</td>
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<td>Reactive</td>
<td>386.00</td>
<td>73.33</td>
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<tr>
<td>Conventional</td>
<td>953.00</td>
<td>77.5</td>
</tr>
<tr>
<td>Reactive</td>
<td>335.00</td>
<td>60.42</td>
</tr>
</tbody>
</table>
Conventional Vs Reactive Charges

Reactive Charge

- Perf. L = 10.39 in
- Perf. D = 0.26 in
- $K = 3.5$ md
- $\Delta P_{\text{inj}} = 335$ psi

Conventional Charge

- Perf. L = 10.27 in
- Perf. D = 0.21 in
- $K = 5.3$ md
- $\Delta P_{\text{inj}} = 351$ psi
Conventional Vs Reactive Charges

CT images taken at the tip of the perforations before acidizing
Conventional Vs Reactive Charges

Reactive Charge

\[ V_{\text{acid}} = 91 \text{ ml} \]

Conventional Charge

\[ V_{\text{acid}} = 95 \text{ ml} \]
Acid Flux Effect on Wormholing

Optimum injection rate (Economides et al. 1994)

![Graph showing the effect of acid flux on wormholing](image-url)
## Perforating Results: Tunnel Dimensions

<table>
<thead>
<tr>
<th>Charge Wt, Grams</th>
<th>Type of Shaped Charge</th>
<th>Perforating Pressure Condition</th>
<th>Inlet Perforation Diameter, inches</th>
<th>Perforation Length, inches</th>
<th>Volume of Perforation, cubic inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Conventional</td>
<td>Balanced</td>
<td>0.206</td>
<td>10.27</td>
<td>0.33</td>
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<tr>
<td>7</td>
<td>Reactive</td>
<td>Balanced</td>
<td>0.257</td>
<td>10.39</td>
<td>0.49</td>
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<tr>
<td>7</td>
<td>Conventional</td>
<td>Overbalanced</td>
<td>0.229</td>
<td>10.27</td>
<td>0.32</td>
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<tr>
<td>7</td>
<td>Reactive</td>
<td>Overbalanced</td>
<td>0.263</td>
<td>10.51</td>
<td>0.50</td>
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<tr>
<td>12</td>
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<td>Balanced</td>
<td>0.320</td>
<td>17.72</td>
<td>1.09</td>
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<tr>
<td>12</td>
<td>Reactive</td>
<td>Balanced</td>
<td>0.390</td>
<td>15.42</td>
<td>1.05</td>
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</tbody>
</table>
# Acidizing Results: Injectivity and Acid to Breakthrough

<table>
<thead>
<tr>
<th>Type of Shaped Charge</th>
<th>Porosity, fraction</th>
<th>Original Rock Permeability, md</th>
<th>Injection ΔP, psi</th>
<th>Acid to Breakthrough, ml</th>
<th>Acid to Breakthrough, PV</th>
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</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>0.257</td>
<td>5.29</td>
<td>375</td>
<td>95</td>
<td>0.1851</td>
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<tr>
<td>Reactive</td>
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<td>3.48</td>
<td>351</td>
<td>91</td>
<td>0.1802</td>
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<tr>
<td>Conventional</td>
<td>0.254</td>
<td>2.67</td>
<td>365</td>
<td>87</td>
<td>0.1712</td>
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<tr>
<td>Reactive</td>
<td>0.256</td>
<td>2.89</td>
<td>298</td>
<td>85</td>
<td>0.1706</td>
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<tr>
<td>Conventional</td>
<td>0.259</td>
<td>3.95</td>
<td>224</td>
<td>56</td>
<td>0.4605</td>
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<tr>
<td>Reactive</td>
<td>0.258</td>
<td>2.58</td>
<td>288</td>
<td>63</td>
<td>0.2589</td>
</tr>
</tbody>
</table>
Conclusions

- CT scan images and effluent fluid samples confirmed the presence of debris.

- Reactive charges tested in this project provide perforation tunnels with higher injectivity.
  - Tunnels with larger diameter.
  - Long fractures at the tip of the tunnels.

- Tunnels created with reactive charges help to generate dominant wormholes.
Path Forward

• Future experiments are planned using larger cores and shaped charges to better simulate field conditions.

• The facilities have been constructed and are in the process of commissioning.
15 KPSI Heated Treatment Cell

Acid and Fluid Injection System
EVALUATION OF PERFORATED CARBONATE CORES UNDER ACID STIMULATION
References


http://www.perf.com/