APP513-025
An Evaluation of the Impact of Reactive Perforating Charges on Acid Wormholing in Carbonates

N.J. Diaz, Texas A&M University, Nathan Clark, M.R.G. Bell, J.T. Hardesty, Geodynamics, Inc. A.D. Hill, H.A. Nasr-El-Din, Texas A&M University, All SPE
Agenda

Background

Objectives

Experimental Procedure and Parameters

Results

Conclusions and Recommendations
Industry Agreement – Over Prediction

- **SPE 124783** “Predicting Depth of Penetration of Downhole Perforators”, Gladkikh et al, Baker
- **SPE 125020** “A Survey of Industry Models for Perforator Performance: Suggestions for Improvement”, Behrmann et al, Schlumberger
- **SPE 127920** “New Predictive Model of Penetration Depth for Oilwell-Perforating Shaped Charges”, Harvey et al, Schlumberger

“The primary conclusions of this work include: (1) historical penetration models tend to over predict penetration at downhole penetrations ... partly due to the industry’s continued reliance on performance into surface targets.”

---SPE125020
Perforation Performance Evaluation

- 22.7 g Charge
- API Cement 39.02”
- 8” Borehole
- 10” Damage Radius
- Perforations Far Field
- Commodity Selection
- Assumed Open
- Doesn’t Match Reality
Perforation Performance Evaluation

- 22.7 g Charge
- Cement Pen
- 8” Borehole
- 10” Damage Radius

- Perforations Near WB
- Performance Valuable
- Geometry Important
- Testing Useful
Background

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

Geological Unit

- Core Sample
- Rubber Sleeve
- Pressure Transducers
- Simulated Casing
- Simulated Wellbore
- Cement Plate
- Gun
- Wellbore

GEOdynamics Reactive Perforating and Acid Wormholing in Carbonates
24-25 April, Asia-Pacific Perforating Symposium, Kuala Lumpur, Malaysia
Experimental Procedure and Parameters

Tip of Perforation

High Density

Inlet of Perforation

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

GEO Dynamics Reactive Perforating and Acid Wormholing in Carbonates
24-25 April, Asia-Pacific Perforating Symposium, Kuala Lumpur, Malaysia
Experimental Procedure and Parameters

![Graph showing pressure vs. time with stages of Acid Injection Starts, Acid Breakthrough, and Steady State Flow.](image)

- **Acid Injection Starts**
- **Acid Breakthrough**
- **Steady State Flow**

GEO Dynamics Reactive Perforating and Acid Wormholing in Carbonates
24-25 April, Asia-Pacific Perforating Symposium, Kuala Lumpur, Malaysia
Experimental Procedure and Parameters
Initial Experiments

Fractures

Acid flowed through the fracture
## 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>
</tr>
<tr>
<td>Reactive</td>
<td>327.00</td>
<td>58.23</td>
</tr>
<tr>
<td>Conventional</td>
<td>321.50</td>
<td>41.67</td>
</tr>
<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>
</tr>
<tr>
<td>Conventional</td>
<td>421.00</td>
<td>64.17</td>
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<tr>
<td>Reactive</td>
<td>386.00</td>
<td>73.33</td>
</tr>
<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
- ΔPinj = 335 psi

**Conventional Charge**
- Perf. L = 10.27 in
- Perf. D = 0.21 in
- K = 5.3 md
- ΔPinj = 351 psi
Conventional Vs Reactive Charges

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

Conventional Charge

\[ V_{\text{acid}} = 95 \text{ ml} \]

Reactive Charge

\[ V_{\text{acid}} = 91 \text{ ml} \]
## 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>
</tr>
<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>
<td>Conventional</td>
<td>Balanced</td>
<td>0.320</td>
<td>17.72</td>
<td>1.09</td>
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<td>12</td>
<td>Reactive</td>
<td>Balanced</td>
<td>0.390</td>
<td>15.42</td>
<td>1.05</td>
</tr>
</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>
</tr>
</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>
<td>0.256</td>
<td>3.48</td>
<td>351</td>
<td>91</td>
<td>0.1802</td>
</tr>
<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>
</tr>
<tr>
<td>Conventional</td>
<td>0.259</td>
<td>3.95</td>
<td>224</td>
<td>56</td>
<td>0.4605</td>
</tr>
<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.
An Evaluation of the Impact of Reactive Perforating Charges on Acid Wormholing in Carbonates

Complete work can be found in SPE 149453
Path Forward

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

• Other Acid / Acid Conditions
15 KPSI Heated Treatment Cell  Acid and Fluid Injection System
SPE-165141

Impact of Charge Type Used in Perforation on the Outcome of Matrix Acid Treatments in Carbonate Formations: A Comparative Study

Ahmed I. Rabie, and Hisham A. Nasr El-Din, Texas A&M University,
John T. Hardesty, Nathan G. Clark, and Matthew R.G. Bell, GEODynamics, Inc.

5-7 June, 2013
## Results & Discussion

### Summary of the Results

<table>
<thead>
<tr>
<th>Type of Charge</th>
<th>Charge Weight, gm</th>
<th>Length of Perforation Tunnel, in.</th>
<th>Cumulative Acid Pore Volume, $PV_{tb}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactive</td>
<td>23</td>
<td>17.6</td>
<td>0.07</td>
</tr>
<tr>
<td>Conventional</td>
<td>23</td>
<td>17.1</td>
<td>0.37</td>
</tr>
</tbody>
</table>
Results & Discussion

Group #2: Deep-Penetration-23 gm Load

Acid Flow through the Core

Reactive

Conventional

Differential Pressure Across the Core, psi

Cumulative Acid Pore Volume, PV
Acidized 23g Tunnels

Reactive

Conventional
New Conclusions

- Perforation of carbonate formations with properly designed reactive liner shaped charges rather than conventional shaped charges should result in more effective matrix acid stimulation as dominant wormholes will be created from the tip of each perforation tunnel, resulting in greater effective wellbore radius for a given volume of acid stimulation.
References


http://www.perf.com/