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State of the Art in Open Hole Sand Control Completions: Advancements & Gaps

Mehmet Parlar
Schlumberger
Outline

• Openhole Sand Control Techniques
• Technique Selection Criteria
• Past Challenges & Advancements in each
  – Open Hole Sand Control Technique along with
    – Inflow Control Devices
    – Zonal Isolation
    – Intelligent Completions
• Gaps
• Conclusions
Productivity Driver for Open Hole

Oilfield Review (Summer 2001)

CASED HOLE FRAC-PACKS
Open Hole Sand Control Techniques

**Stand Alone Screen (SAS)**
(WWS, Metal Mesh)

**Expandable Screen (ES)**
(Compliant, non-Compliant)

**Gravel Pack (GP)**
(α/β, Alternate Path, α/α, β-only)

Open Hole Frac Pack?
(SPE 73757, 84416, 135441)
Selection Considerations

• Technical
  – PSD, rock strength, shale breaks & frequency, zonal isolation
  – Limitations of each technique
  – Laboratory testing

• Tolerance to solids production
  – Surface facilities, disposal, erosion

• Economics, Risk, Logistics
  – Total completion cost & cost of failure

• Comfort (Perceived Risk) Factor
Particle Size Distribution & Its Representation

\[ D_{50}, C_U = \frac{D_{40}}{D_{90}}, C_S = \frac{D_{10}}{D_{95}} \]

% Fines (\(< 44 \mu\))
Commonly Used Criteria

*SPE 39437, Tiffin et al.*

- **CS** (\(= \frac{D_{10}}{D_{95}}\)) < 10 \(\Rightarrow\) SAS
  - **CU** (\(= \frac{D_{40}}{D_{90}}\)) < 3 and Fines < 2% \(\Rightarrow\) WWS
  - 3 < **CU** < 5 and 2% < Fines < 5% \(\Rightarrow\) Mesh

- **CS** > 10 or **CU** > 5 or Fines > 5% \(\Rightarrow\) GP

• Adapted by Price-Smith et al. *(SPE D&C, Sep. 2003)*

• Challenged by
  • Mathisen et al. citing field experience *(SPE 107539)*
  • Chanpura et al. thru lab evidence *(SPE 127931)*
Standalone Screens (SAS)

- Bad taste from early stages of learning curve
  - Screen plugging when screens installed in
    - not well-conditioned mud
    - well-conditioned mud but mixing of formation sand with mud (where sanding occurs on Day 1)
  - wells where no mud cake cleanup performed, with mixing of mudcake & formation sand (sanding occurs on Day 1)
# Screen Testing for SAS

<table>
<thead>
<tr>
<th></th>
<th>Slurry Tests</th>
<th>Prepack Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulates</td>
<td>Gradual failure</td>
<td>Hole collapse</td>
</tr>
<tr>
<td>Concentration</td>
<td>Low (&lt;1%)</td>
<td>High (~ 50%)</td>
</tr>
<tr>
<td>Pack forms</td>
<td>During test</td>
<td>Start of test</td>
</tr>
<tr>
<td>Pumped at</td>
<td>Constant Q</td>
<td>Constant P</td>
</tr>
</tbody>
</table>

- Sand produced vs. Time *(or Sand Injected)*
  - Sand retention efficiency
- Pressure *(or Flow Rate)* vs. Time
  - “Plugging” tendency
- Size Distribution of Produced Solids
  - Erosion considerations
Drawbacks of Current Slurry Test Methods & Interpretation

- Selection based on relative ranking, and even then NOT straight forward:
  - Tests stopped prematurely (100 psi limit)
    - Once sand production stops or stabilizes (true fines problem), slope should be independent of screen
  - Effects of open flow area, converging flow and Forchheimer flow effect
  - Flow rates ~ 1-2 orders of magnitude higher vs. Field
  - “Plugging” is OFTEN coverage of screen openings by sand.

Favors Mesh Screen vs. Wire Wrap Screen
Plugging with Sand alone: Rare

Plugging due to mixing of sand with:
- Shales/Silts (annular isolation) or
- Mud/Mudcake (displacements/cleanup)
30 of 45 WWS (and 70 of 140 PMS) tests with $U_C : 5 – 26$ satisfied a very conservative sand retention criterion.
## RECENT MODELING WORK

<table>
<thead>
<tr>
<th>PRE-PACK</th>
<th>SLURRY</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MESH GEOMETRY</strong> (Metal Mesh/Premium)</td>
<td><em>SPE 146656</em>, Mondal et al. (2011)</td>
</tr>
</tbody>
</table>
Prepack: Numerical Simulations

\[ N_p = \alpha \left( \frac{D_p}{w} \right)^{-\beta} \]

SPE 134326
Slurry: Monte Carlo Simulations & Analytical Solutions

• Sand retention purely size exclusion
  – No bridging

• Given a slot opening and a PSD
  • Pick particles at random
  • Produce if smaller than slot and retain if bigger.
  • Determine sand production per unit area

\[ M_{prod} = \frac{\rho \pi}{6w} \left[ \left(1 - \frac{X}{X}\right) d_x^2 \right] \left( \frac{A_s}{A} \right) \]

\[ d_x = \sqrt{\frac{X}{\sum_{i=1}^{n_d} \left( \frac{x_i}{d_i^2} \right)}} \]
Comparison to Experimental Results

![Graph showing cumulative percent retained vs. particle size (micron)]

**TABLE 4—COMPARISON OF SAND PRODUCTION FROM MONTE CARLO SIMULATIONS RESULTS WITH EXPERIMENTAL DATA**

<table>
<thead>
<tr>
<th></th>
<th>MC Simulations (g/cm²)</th>
<th>Data (g/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test1</td>
<td>0.0914</td>
<td>0.0919</td>
</tr>
<tr>
<td>Test2</td>
<td>0.0468</td>
<td>0.0907</td>
</tr>
<tr>
<td>Test3</td>
<td>0.2073</td>
<td>0.0754</td>
</tr>
</tbody>
</table>
Recent Experimental Data

<table>
<thead>
<tr>
<th>Sand Production In lb/ft²</th>
<th>EXPERIMENT</th>
<th>MONTE CARLO</th>
<th>ANALYTICAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSD-a</td>
<td>0.40</td>
<td>0.42</td>
<td>0.43</td>
</tr>
<tr>
<td>PSD-b</td>
<td>0.26</td>
<td>0.26</td>
<td>0.26</td>
</tr>
</tbody>
</table>

If accurate PSD ➔ MODEL IS PREDICTIVE
Conclusions of SPE 143731

• Analytical & numerical solutions available now for prediction of slurry sand retention tests
  • Analytical solution gives > 90% of the answer because after the first layer of sand particles cover the slots sand production ~ stops and screen has NO FUNCTION.
  • Conventional fines definition (<44 Microns) is IMMATERIAL to selection of screen.
  • What matters is the COARSER portion of the PSD.
Expandable Screens

• Viewed as
  – Elegant alternative to gravel packing by some
    • simpler to install, and
    • up to a certain length lower cost than gravel pack
  – Expensive SAS by some others
    • Wellbore collapse at onset of hydrocarbon production
  – New technology by some others

• Had its successes & failures much like others
  – SPE 97282
Expandable Screens

• Technology evolved substantially to single trip installation with zonal isolation capability *(SPE 106342)*

• Compliant versus non-Compliant
  • How much of a gap is small enough?
  • Finding the right application for each?
    • Proper geomechanical work required.
    • Some of the failures associated with loss of sand control attributed to “localized collapse”

• Cased Hole Producers, especially in high transmissibility formations: Abuse of ESS technology
Open Hole is Forgiving

Fig. 2—Comparison of production rates from gravel-packed openhole and cased-hole completions. Open hole: 50-ft vertical interval, 1-darcy formation, 8.5-in. hole; cased hole: 12 shots/ft, 0.75-in. collapsed perforations. IPR = Inflow performance relationship, TIC = tubing-intake curve, CH = cased hole, and GP = gravel pack.

- SAS/ESS in Cased Hole NOT the best choice for "high rate producers".
Open Hole Gravel Pack (OHGP)

• Why would anyone go through additional pumping stage if Screen Only will do it?

  – Not every well is an SAS candidate
    • Frequent thin shale breaks (too many packers)
    • Zero tolerance to sand production
Challenge: No More

• Swabbing during tool movements
  • Filtercake liftoff & leakoff at start of circulation (*SPE 48976*)
  • **Anti-Swab Tools** (*SPE 74492*)
    • Hydraulic communication

• Post-Gravel Pack Filtercake Cleanup
  • Required Coiled Tubing
  • **Tools with Post-GP Circulation capability** (*SPE 50651*)
Challenge: No More

• Reactive Shales
  – Shale swelling and/or collapse before or after screen installation
    • *SPE 89815, 90758, 107297*
  – Shale dispersion in Carrier Fluid

• Shale Stabilizers *(SPE D&C, 2008)*
  • Displacement and Carrier Fluids *(SPE 121834)*
Challenge: No More

- Reactive Shales- Contd.
  - Oil-Based Drilling
    - Oil-Based Gravel Packing
      - Viscous Packing (*SPE D&C, 2006*)
      - $\alpha/\beta$ Packing (*SPE D&C 2009*)
    - Water-Based Gravel Packing
      - Two-Trip (*SPE 48976, 73727, 89815, 90758*)
      - Single-Trip w/ Screens RIH in Oil Based Fluids
        - Conditioned OBM (*SPE 90758, 98146, 115434*)
        - Solids Free OBM in Open Hole & Brine in Cased Hole (*SPE 134319*)
Challenge: No More

- Narrow Operational Window (Fracturing)
  - Loss of circulation & premature screenout
    - Diverter Valves (SPE 71668)
      - World Record: 8,305 ft. in 2003 (OTC 15281)
    - Light Weight Gravel (SPE 17169, 96257)
    - Friction Reducer (SPE D&C, Sep 2010)
      - These solutions can take α/β packs a long way!
    - Alternate Path (SPE 86532)
      - Transport/Packing Tubes, Nozzles, Concentric Entrance, Swell Packers
Zonal Isolation

• Considered as the biggest disadvantage of open holes vs. cased holes

  – Hydraulically Inflated Packers
  – Hydro-Mechanically Set Packers (SPE 77214)
  – Swell Packers (SPE 78312)
  – Expandable Packers (SPE 106342)
Zonal Isolation

– Gravel Packing
  – Full isolation with complete pack still a matter of debate
  – Isolation packer set
    – After gravel packing (SPE 77214)
    – Before gravel packing [SPE 146361, SPE 146803 (swell packers) ➔ Alternate Path]
Inflow Profile Control

• Higher inflow near heel or high perm streaks
  – Premature water or gas breakthrough
  – **Inflow Control Devices** (*SPE 108700, Review*)
    – Channel Type (*SPE 78293*)
    – Nozzle Type (*OTC 19172*)
    – Hybrid Type (*OTC 19811*)
  – Many SAS Applications (e.g., *SPE 107539*)
  – 1 documented OHGP (*SPE D&C, Mar 2008*)
    – Non-ICD screen at toe
    – Some 2 trip installations
    – Ongoing developments
Inflow Profile Control

• Ability to adjust flow, including shut-off
  – Active Inflow Control Devices (IPTC 12145, *Comparison of Active vs Passive*)
    – Many applications to date injectors & producers
      – Some limitations for active flow control devices
        – Control lines
      – Open hole applications limited to ~ 2 compartments in cases when another tubing is run inside screen
      – Alternatively, sliding sleeve type solutions exist
        – Require intervention (e.g., CT run)
Intelligent Completions

• Real time measurements along sandface
  – Fiber Optic
    • Distributed Temperature Sensor
    • Pressure Gauge
    • Distributed Vibration Sensor
• Communication of Power & Data
  – Between upper & lower completion in subsea completions *(SPE D&C, June 2010)*
• Active Flow Control along sandface
Gaps

• Selection guidelines based on solid grounds
  – SAS (WWS vs PMS) vs ESS vs OHGP
  – Not only insufficient information sharing, particularly of failures, but also lack of thorough understanding why.

• Predictive models for sand production through sand control screens
  – Good results for laboratory environments, but even that part is not yet complete (accuracy of PSD measurements: Sieve, Laser ??)
  – What do these really say about field scenario?
Gaps

• Laser vs Sieve for PSD

• Particle Size Distribution Log
  – Ongoing work in various companies

• Impact of bean up (ramp up) procedures
  • How, under what conditions, why?

• Real time data during installation & execution

• Sandface measurements combined with active flow control
Conclusions

• Significant advancements made in the last decade
  – Retention by SAS being better understood & limits are deservedly being pushed
  – ESS has come a long way to single trip installation with zonal isolation
  – Many OHGP challenges overcome, wells longer than most of us interested in drilling can now be gravel packed (α/β, APS)
  – Zonal isolation, ICDs, intelligent completions

• Although some gaps do exist
Thank you for your attention.
Questions ?
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