Novel Workflow to Optimise Annular Flow Isolation in Advanced Wells

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Outline

- Introduction
- Problem Definition and Traditional AFI (Annular Flow Isolation) Design Workflows Review
- Novel Workflow to optimise the number and Location of AFIs
- Conclusions
Advanced Well Completion (AWC)

“A completion capable of managing the fluid inflow to or outflow from the wellbore to optimise the well performance”

Main components:

- Interval Control Valve (ICV)
- Inflow Control Device (ICD)
- Autonomous Inflow Control Device (AICD)
- Annular Flow Isolation (AFI)
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AFI Placement Problem

Question:
How to optimise the design of a limited number of AFIs that we ensure the maximum benefit of an (A)ICD completion?

Main answers in literature
AFI should be installed:
1. At every single (A)ICD joint: [OTC 20348, ...]
2. Where there is a permeability contrast. [SPE 85332, ...]
3. Based on analysis of Logging While Drilling data. [SPE 105036, ...]
4. With the same spacing along wellbore. [SPE 120795, ...]

None of them were found appropriate methodology to optimise AFI design because they:
1. Don’t include the dynamics of the Well-Reservoir interaction
2. Don’t consider the practical and economical issues
AFI Location and Number

Heterogeneity, Draw down

Heel

K/2

K

K/2

Deviated well

Heel

K/2

K

K/2

Higher Pressure Loss in Tubing

Heel

K/2

K

K/2

Heterogeneity and ICD Design

Heel

K/2

K

K/3

✓ Total Oil Production (FOPT)
✓ Net Present Value (NPV)

Constraints:
✓ Liquid Production Rate
✓ Tubing Head Pressure

AFI Design

Objective Function

Heterogeneity of Reservoir Properties

Wellbore configuration

✓ Permeability
✓ Reservoir Pressure
✓ Fluids Saturations

Designs:
✓ Constant Strength
✓ Variable Strength

Production constraint

(A) ICD design
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  Workflows Review
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Uneven inflow from heterogeneous reservoir occurs due to differing reservoir properties (e.g. permeability, pressure)

(A)ICD-AFI completion provides variable annulus pressures required to balance fluid inflow from heterogeneous reservoir.

\[ Q_i = J_i (P_i - P_{ai}) \]  

Darcy Equation

\( P_{ai} \): Annulus pressure of each zone across each layer
Average Annulus Pressure

- Annulus pressure includes the effects of all the dynamic and static important parameters affecting AFI design.
- Its average covers the variation in layers’ production with time.

**AAPDR: Average Annulus Pressure Difference Ratio**

\[ \text{AAPDR} = \frac{P_{\text{res}} - P_{\text{l}}}{P_{\alpha}} \]

- \( P_{\text{res}} = \) Reservoir Pressure
- \( P_{\text{l}} = \) Tubing Pressure
- \( P_{\alpha} = \) Annulus Pressure
- \( J = \) Productivity Index
- \( \alpha = \) ICD strength

Annulus pressure includes the effects of all the dynamic and static important parameters affecting AFI design. Its average covers the variation in layers’ production with time.
AAPDR Workflow

\[
(X) \text{ Index} = \frac{(X_{\text{case}} - X_{\text{open-hole}}) \cdot (X_{\text{max AFI}} - X_{\text{open-hole}})}{X_{\text{max AFI}} - X_{\text{open-hole}}}
\]

\(X\): NPV, FOPT, etc.

\[
AAPDT = \sum_{i=1}^{n} AAPD_i
\]

\[
AAPDR_i = \frac{AAPD_i}{AAPDT}
\]

Lost \(X = 100\% - (X \text{ Index})\)

AAPD = Average Annulus Pressure Difference of neighbour compartments

AAPDT = Total Average Annulus Pressure Difference

\(i\) = Each couple of two neighbour compartments

Start
Well-Reservoir model preparation when AFI placed at every single ICD joint

Run the model for the complete life time of the well and define the target loss index

Read Annulus Pressure and calculate AAPD, AAPDT and AAPDR for each two adjacent compartments

Rank AFIs based on their AAPDR values

Remove extra AFIs, based on the ranking, to reach maximum, practically possible AFI installation limit and run the simulator with the new ICD-AFI design

Is the Loss index OK? and

Is the number of AFIs OK?

Based on the AAPDR ranking, remove next AFI and run the simulator

Is the Loss index equal or lower than the target Loss index

Both Yes

Finish
AAPDR Workflow

**Assumptions:**

1. (A) ICD design is already chosen.
2. No cross flow from the tubing to the annulus.
3. Maintaining the degree of equalisation, obtained by the Ideal AFI completion, as far as possible is the most important factor to improve the oil production.
4. Same annulus specification for the whole well length.

**APPDR Workflow is:**

1) Simple and quick
2) Based on Reservoir-Wellbore interaction performance
3) Able to rank the AFIs to predict the relative impact of removing an AFI
### PUNQ_S3 Model

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description (Value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production Constraint</td>
<td>Liquid rate: 1000 (SM3/D), THP= 10BAR</td>
</tr>
<tr>
<td>Well length</td>
<td>3700 m</td>
</tr>
<tr>
<td>Well Depth Change</td>
<td>35 m</td>
</tr>
<tr>
<td>Average friction pressure</td>
<td>3.5 BAR</td>
</tr>
<tr>
<td>production time</td>
<td>33 Years</td>
</tr>
</tbody>
</table>

**Objective Function** => **Net Present Value (NPV)**

where:

- **Oil Price:** (60 $/STOB)
- **Gas Price:** (2 $/MSCF)
- **Water Handling Cost:** (3 $/STWB)
- **Interest rate:** 10% (CAPEX, OPEX=0)

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**Fluid Distribution – Open-Hole Completion**

- **Cumulative Gas Percentage**
- **Cumulative Water percentage**
- **Cumulative Oil Percentage**
- **Cumulative Liquid percentage**

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**Absolute permeability values along the well length, mD**

- 906
- 677
- 709
- 469
- 53.5
- 19
- 28.4
- 36.5
- 276.7
- 967.5
- 395.5
- 415
- 843.3
- 850
- 862
- 890
- 726.5
- 775
- 442
- 174
(1000 Sm³/D Liquid rate, THP 10 bar)

**AFI Settings - Liquid Rate Production**

- **21 ICDs**
- **20 places to install AFI**

### NPV Index for different AFI designs

<table>
<thead>
<tr>
<th></th>
<th>ICD (4*1.6 mm)</th>
<th>ICD (2*2.5 mm)</th>
<th>ICD (2*4 mm)</th>
<th>ICD (4*4 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same Spacing (360m)</td>
<td>81.40%</td>
<td>82.30%</td>
<td>82%</td>
<td>82.75%</td>
</tr>
<tr>
<td>AFI at permeability contrasts</td>
<td>67.50%</td>
<td>66%</td>
<td>66.50%</td>
<td>67%</td>
</tr>
<tr>
<td>Optimised AFI placement</td>
<td>99%</td>
<td>98.75%</td>
<td>98.30%</td>
<td>98.20%</td>
</tr>
<tr>
<td>AAPDR</td>
<td>98.30%</td>
<td>98.50%</td>
<td>98.73%</td>
<td>98.76%</td>
</tr>
</tbody>
</table>

Maximum possible practical AFI was selected to be 10.
Conclusions

- The reservoir heterogeneity, well configuration, and production constraints are important in AFI design.
- To optimise the AWC design, a dynamic Well-Reservoir simulator approach is recommended rather than the approach based on a static model.
- AAPDR workflow based on 1 dynamic Well-Reservoir simulation was proposed. It is simple and quick to determine the sub-optimum AFI design.
- (A)ICD strength and AFI configuration are mutually dependent when looking for an optimum well completion design. They require simultaneous analysis during such design.
We thank the sponsors of the “Value from Advanced Wells” JIP:

Thank you for Your Attention

Any Questions and Comments?