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Managed Pressure Drilling – Experiences and Way Forward

Muhammad A. Muqeem, Ph.D., P. Eng.

Saudi Aramco

SPE Distinguished Lecturer Program
Outline

• Definition
• The Big Challenge
• Impact of the Technology
• Benefits & Case Histories
• What’s Next
• Conclusions
Challenging Wells

Expensive Wells
“The world is running out of conventional prospects…. but don’t worry. Managed Pressure Drilling (MPD) is one enabler for tackling “undrillable” wells.”

*Signa Engineering Corp. website*
IADC Definition – Managed Pressure Drilling

“an adaptive drilling process used to precisely control the annular pressure profile throughout the wellbore. The objectives are to ascertain the downhole pressure environment limits and to manage the annular hydraulic pressure profile accordingly.”
The Big Challenge
Conventional Drilling

Bottomhole circulating pressure (BHCP) is manipulated by only two variables:

\[ \text{BHCP} = \text{Hydrostatic Pressure} + \text{Friction Pressure} \]
Managed Pressure Drilling

Bottomhole circulating pressure is manipulated by three variables:

\[ \text{BHCP} = \text{Hydrostatic Pressure} + \text{Friction Pressure} + \text{Surface Back Pressure} \]
MPD – Fundamental Principles

Pressure

TVD

Shoe

Fracture/Losses

Drilling Window

Pore Pressure
MPD – Fundamental Principles (cont.)

1. Static Pressure
2. Apply Choke Pressure
3. Static+Choke Pressure
Fracture/Losses

TVD
Shoe
MPD – Fundamental Principles (cont.)

1. Apply Choke Pressure
2. Dynamic #1
3. Pore Pressure
4. Dynamic #2
5. Apply More Choke Pressure
6. Fracture/Losses
Variations of MPD

- Constant Bottomhole Pressure (CBHP)
- Pressurized Mudcap Drilling (PMCD)
- Dual Gradient Drilling (DGD)
Constant Bottomhole Pressure (CBHP)

- “ECD Management”
- Narrow drilling window
- Slightly lighter fluids than conventional
- Influx is prevented by backpressure
- Intent to keep BHCP as constant as possible.
Pressurized Mudcap Drilling (PMCD)

- Total loss circulation
- Well control challenges
- Failure to reach TD
Dual Gradient Drilling (DGD)

- High equivalent circulating density
  - Ultra deepwater
  - Extended reach
  - Narrow sidetrack drilling
- Subsea RCD
- Subsea pumps
Dual Gradient Drilling Schematic

- **DUAL GRADIENT 'DILUTED' MUD HYDROSTATIC PRESSURE**
- **SINGLE GRADIENT MUD HYDROSTATIC PRESSURE**
- **SECTION DRILLABLE WITH SINGLE GRADIENT**
- **SEAWATER GRADIENT**
- **SEAFLOOR**
- **DUAL GRADIENT 'DOWNHOLE' MUD HYDROSTATIC PRESSURE**
- **PORE PRESSURE**
- **FRACTURE GRADIENT**
- **DEPTH**
- **PRESSURE**

MUD WEIGHT MUST REMAIN WITHIN THESE LIMITS.
MPD enabling tools

- Rotating Control Diverter (RCD)
- Dedicated choke
- Mass flow meter
- Drill string floats
- Continuous circulating device
- Separation package
- Training
MPD Equipment Layout (Closed)

*Medley & Reynolds, "Distinct variations of MPD exhibit application potential"
Rotating Control Diverter

RCD

RCD Control Console

*Weatherford
MPD Choke Manifold

Choke A

Mass Flow Meter

Choke B

Fluid From Well

*Schlumberger
Separation Package

- Multi-phase separator
- Separates gas from drilling mud
- Sends mud to active system for further processing
Benefits

- Reduces non productive time
- Enables the use of a lighter weight mud
- Reduces solids invasion to improve productivity
- Avoids fluid losses, minimizes mud costs
Benefits (continued)

- Significant increase in safety and efficiency
- Mitigates potential stuck pipe and well control incidences
- Allows drilling in environmentally sensitive and hazardous ($H_2S$) areas
- Detects gas kicks quickly using the intelligent control system
2012 MPD Preventable NPT (MENA Region)

- Wellbore Instability: 3.7%
- Lost Circulation: 4.8%
- Stuck Casing: 1.6%
- Stuck Pipe: 11.4%
- Well Flowing/Kick: 2.0%
- Others: 76.5%
Impact of MPD (MENA Region)

- MPD preventable NPT ~ 23.5%
- Average onshore rig spread
  - Oil well drilling cost/foot ~ 642 USD
  - NPT cost per foot ~ 151 USD
- Average cost avoidance for a 15,000 ft well ~ 2.3 MM USD
### 1st MPD Well - Kingdom of Saudi Arabia

<table>
<thead>
<tr>
<th>8-3/8” Section</th>
<th>Offset Well</th>
<th>MPD Well</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Drilling Days</td>
<td>65</td>
<td>40</td>
</tr>
<tr>
<td>Days spent on Well Control</td>
<td>7.6</td>
<td>1.1</td>
</tr>
<tr>
<td>Days spent on Reaming</td>
<td>2.8</td>
<td>0.8</td>
</tr>
</tbody>
</table>

*SPE/IADC 113679*
Case History – MENA Region

Objectives:

• Enable use of a lighter mud system to avoid unnecessary and excessive overbalance
• Keep drilling fluids out of the formation
• Reduce/Eliminate the potential NPT related to pipe stuck scenarios and well control events
Case History – MENA Region (contd.)

Average Ft/Day

W-A  W-B  W-C  W-D  W-E  W-F  W-G  W-H

30% increase
Case History – MENA Region (contd.)

– Reduced stuck pipe & fishing NPT by 95%
– Allowed reducing the drilling mud weight from 14 ppg to 10.5 ppg improving drilling efficiency
– Reduced solids invasion and improved water injectivity in the lateral
– Average number of bit/motor runs increased three-folds
### Case History – Shale Plays (North America)

<table>
<thead>
<tr>
<th>Average values</th>
<th>6 Offset Wells</th>
<th>4 MPD Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mud weights at TD, ppg</td>
<td>16.5</td>
<td>15.0</td>
</tr>
<tr>
<td>Days for lower hole section</td>
<td>33.0</td>
<td>16.5</td>
</tr>
<tr>
<td>Total days to TD</td>
<td>62</td>
<td>40</td>
</tr>
</tbody>
</table>

*AADE-11-NTCE-55*
Steps for MPD Technology Acceptance

– Better communication of benefits
– To include cost/benefit analysis
– Reduce cost of MPD
– More successful applications
– Extensive training
Offshore wells using MPD in 5 years

- IOCs: 28%
- NOCs: 39%
- Independents: 36%
- Total Operators: 33%
- Service Companies: 43%
- TOTAL: 40%

*Journal of Petroleum Technology: February 2011
What’s Next

– Deepwater MPD
– Improved modeling of subsurface conditions (multiphase annular flow)
– Greater automation (choke)
– Data availability in certain environments (compressible fluid) using wired drillpipe
– Barrier Monitoring
What’s Next (continued)

– Mainstream technology in the near future
– “Un-drillable” wells are becoming “drillable”
– Unconventional wells are being drilled using MPD
– Managed Pressure Cementing
– Methane Hydrates
Methane Hydrates – The Next Frontier

• Major Challenges:
  - Narrow margin between pore pressure and fracture gradient in ocean sediments
  - Surface hole instability
  - Subsidence caused by hydrate production
  - Manage temperatures & pressures to limit hydrate dissociation in wellbore
Methane Hydrates – The Next Frontier

- MPD Toolbox:
  - Rotating control diverter
  - Drilling choke system
  - Non-return valves
  - Multiphase circulation pumps
  - Multiphase separation system
Conclusions

– Wells are becoming more expensive and difficult to drill
– MPD is evolving into a key enabling technology to tackle those challenging wells
– Numerous case histories in all types of well indicate that MPD is here to stay
Conclusions (continued)

– MPD is a complex, multidisciplinary activity which requires proper engineering, HSE and project management skills
– Enhances formation evaluation
– Fit for purpose training is a prerequisite for successful implementation
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