Rotary Steerable System workshop

Brisbane
21-Oct-2015
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PathFinder – Schlumberger Drilling Engineer
Agenda

• Introduction
• History of directional drilling
• History of Rotary Steerable System (RSS)
• Benefits of Rotary Steerable System
• RSS steering principle
• Existing RSS in the market
• Case studies
• What is next?
Introduction

• Presenter’s background
  – Joined the industry in 2000 as MWD field Engineer
  – Worked as field engineer until 2005
  – Worked as Operation support until 2010
  – Been working as Drilling Engineer for PathFinder, A Schlumberger company
  – Being SPE member.

• Quick audience’s survey
  – Role / Experience
  – RSS experience
History of directional drilling
History of directional drilling

• The late 1920’s
  – The first application of oil well surveying using the acid bottle inclinometer

• 1929
  – the directional inclinometer with the magnetic needle was introduced

• 1930
  – The first controlled directional well was drilled (was initially for unethical proposes, to cross property lines)
History of directional drilling

• 1934
  – controlled DD was used to kill a wild well
  – started to apply principles of controlled DD

• Directional Drilling definition
  – is the science of deviating a well bore along a planned course to a subsurface target whose location is a given lateral distance and direction from the vertical.
History of directional drilling

WHY DIRECTIONAL WELLS

- Sidetracking
- Inaccessible Locations
- Salt Dome Drilling
- Fault Controlling
History of directional drilling

WHY DIRECTIONAL WELLS

- Multiple Exploration
- Multilateral Offshore
- Relief well
- Short, Medium, & Long Radius
History of Rotary Steerable System

• Disadvantages of conventional mud motor
  – Slow rate of penetration (ROP) while sliding
  – Orienting mud motor for steering is time consuming
  – Unable to transfer weight to bit due to high friction
  – Pipe buckling while sliding
  – Increase differential sticking risk while sliding
  – Bit aggressiveness dependent
  – Introduce micro dogleg
    • high borehole tortuosity
    • Greater torque and drag
History of Rotary Steerable System
History of Rotary Steerable System

• 1st RSS system – Vertical drilling system in Continental Deep Drilling (KTB) project – southern Germany in late 1980s.

• System contains
  – A near-bit inclination sensor
  – A downhole processor
  – Steering ribs on a stabilizer just above the bit

• System principle
  – Closed-loop process
In 1993, Agip S.p.A. and Baker Hughes Inteq developed RCLS – Rotary closed loop system.
History of Rotary Steerable System

• In 1997, BP drilled 1st ERD well with departure over 10km using RSS* from Camco Ltd (lately acquired by Schlumberger)

*SPE#38353
Benefits of Rotary Steerable System
Continuous Rotation while steering

- Steady Deviation Control
  independent of bit torque. Problems of controlling tool face through elastic drill string are reduced
- Cut AFE Time
  Drill faster while steering and reduce wiper trips
- Smoother Hole
  Tortuosity of well bore is reduced by better steering
- Cleaner Hole
  Continuous rotation
- Less Drag
  Continuous rotation improves control of WOB
- Less Risk of Stuck Pipe
- Completion cost and risk is reduced
- Work Over is made easier
- Longer Horizontal Range
  Geosteered in reservoir
- Complex Well Designs
  3D targets, Uphill drilling
- Longer Extended Reach
  without excessive drag
- Fewer Platforms to develop a field
- Well Downsizing
  Fit for purpose wells
- Fewer Wells to exploit a reservoir
- Less Cost per Foot

Rotary Steerable Benefits
Benefits of RSS

• Directional control from surface
  – 100% rotary drill
  – Downlink command while drilling
    • On or off bottom
    • Using mud flow or surface RPM
  – Kick off from vertical, build/drop/turn – 3D profile
  – Open hole sidetrack (with or without cement plug)
  – Long to medium radius profile (up to 18 deg/30m)
  – Extended Reach (ERD) application
Benefits of RSS

- Better rate of penetration
  - Rotate 100% - effective weight transfer to bit
  - Sliding ROP << rotary ROP

Beyond 2,000-m MD, ROP decreased dramatically with the PDM but remained consistently high with the RSS.
Benefits of RSS

- Better rate of penetration
  - PDM vs RSS
Benefits of RSS

• Less risk of being differential stuck
  – Motor BHA stays non-rotated while sliding
  – RSS BHA rotates all the time
    • Some RSS systems has non-rotating sleeves
    • Some RSS systems has all external parts rotates
Benefits of RSS

• Better hole cleaning with continuous, high rotation speed in high angle wells (over 30 deg incl)
  – Active flow area is at the top
  – Pipe and cuttings lay along bottom
  – Require mechanical agitation to get cuttings into the fluid flow

• Typical surface rotary speed
  – Mud motor BHA: 50-60 RPM and upto 80 RPM
  – RSS BHA: 100-200 RPM
Benefits of RSS

- Better borehole quality
  - Over-gauge hole by Mud motor BHA
  - Minimum micro-dogleg due to sliding
Benefits of RSS

- Overcome pipe buckling issue with sliding mode
Benefits of RSS

- Overcome pipe buckling issue with sliding mode

Buckling analysis with mud motor BHA

Buckling analysis with RSS BHA
Benefits of RSS

• Vertical drilling in highly dip formation

Kela field in Tarim, China
RSS Steering principle

This section has animations and images removed from original version presented in SPE workshop due to copyright*
RSS Steering principle

• Push the bit
  – Deflect drill bit by pushing tool’s collar to opposite desired direction while the BHA being rotated

• Point the bit
  – Deflect drill bit off-center of the tool – Pointing the bit to desired direction while the BHA being rotated

• Hybrid
  – Deflect drill bit off-center of the tool using pushing mechanism within tool’s collar
Existing RSS in the market
## Existing RSS in the market

### • Baker Hughes Auto Trak family

<table>
<thead>
<tr>
<th>Tool name</th>
<th>Steering principle</th>
<th>Max DLS (deg/30m)</th>
<th>Downlink</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>AutoTrak curve</td>
<td>Hybrid of point and push</td>
<td>15</td>
<td>Flow rate</td>
<td>High DLS RSS</td>
</tr>
<tr>
<td>AutoTrak G3</td>
<td>Hybrid of point and push</td>
<td>6.5-10</td>
<td>Flow rate</td>
<td>RSS+MLWD</td>
</tr>
<tr>
<td>AutoTrak Xtreme</td>
<td>Hybrid of point and push</td>
<td>6.5-10</td>
<td>Flow rate</td>
<td>RSS+MLWD+Motor assist</td>
</tr>
<tr>
<td>AutoTrak Express</td>
<td>Hybrid of point and push</td>
<td>6.5-10</td>
<td>Flow rate</td>
<td>Standard RSS</td>
</tr>
<tr>
<td>AutoTrak V</td>
<td>Hybrid of point and push</td>
<td>Vertical</td>
<td>Flow rate</td>
<td>Vertical drilling</td>
</tr>
</tbody>
</table>

[AutoTrak review](#)
### Existing RSS in the market

#### Halliburton Geo-Pilot family

<table>
<thead>
<tr>
<th>Tool name</th>
<th>Steering principle</th>
<th>Max DLS (deg/30m)</th>
<th>Downlink</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>EZ-Pilot</td>
<td>Point the bit</td>
<td>8</td>
<td>Negative pulse/Collar RPM</td>
<td>Standard RSS</td>
</tr>
<tr>
<td>Geo-Pilot Dirigo</td>
<td>Point the bit</td>
<td>10-15</td>
<td>Negative pulse</td>
<td>High DLS RSS</td>
</tr>
<tr>
<td>Geo-Pilot XL</td>
<td>Point the bit</td>
<td>5-10</td>
<td>Negative pulse</td>
<td>Harsh drilling environment</td>
</tr>
<tr>
<td>Geo-Pilot GXT</td>
<td>Point the bit</td>
<td>5-10</td>
<td>Negative pulse</td>
<td>Motor assist</td>
</tr>
<tr>
<td>SOLAR Geo-Pilot</td>
<td>Point the bit</td>
<td>5-10</td>
<td>Negative pulse</td>
<td>High Temperature (175degC)</td>
</tr>
</tbody>
</table>

[Geo-pilot review]
Existing RSS in the market

- Schlumberger PowerDrive system

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<th>Max DLS (deg/30m)</th>
<th>Downlink</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>PowerDrive Xceed</td>
<td>Point the bit</td>
<td>6.5-8</td>
<td>Flow rate</td>
<td>Harsh drilling</td>
</tr>
<tr>
<td>PowerDrive X6</td>
<td>Push the bit</td>
<td>4-8</td>
<td>Flow rate</td>
<td>Standard RSS</td>
</tr>
<tr>
<td>PowerDrive Orbit</td>
<td>Push the bit</td>
<td>3-8</td>
<td>Flow rate/RPM</td>
<td>More robust for harsh drilling</td>
</tr>
<tr>
<td>PowerVorteX</td>
<td>Point /push</td>
<td>3-8</td>
<td>Flow rate</td>
<td>Motor assist</td>
</tr>
<tr>
<td>PowerV</td>
<td>Point /push</td>
<td>vertical</td>
<td>Flow rate</td>
<td>Vertical drilling</td>
</tr>
<tr>
<td>PowerDrive Archer</td>
<td>Hybrid of point and push</td>
<td>15-18</td>
<td>Flow rate/RPM</td>
<td>High DLS RSS</td>
</tr>
<tr>
<td>PowerDrive ICE</td>
<td>Push the bit</td>
<td>8</td>
<td>Flow rate/RPM</td>
<td>High tem RSS (200 degC)</td>
</tr>
</tbody>
</table>

[Power Drive Archer review](#)  [PowerDrive Xceed review](#)
### Weatherford Revolution RSS family

<table>
<thead>
<tr>
<th>Tool name</th>
<th>Steering principle</th>
<th>Max DLS (deg/30m)</th>
<th>Downlink</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revolution Core</td>
<td>Point the bit</td>
<td>6-10</td>
<td>Negative pulse/RPM</td>
<td>Standard RSS</td>
</tr>
<tr>
<td>Revolution Heat</td>
<td>Point the bit</td>
<td>6-10</td>
<td>Negative pulse/RPM</td>
<td>High temp RSS (175degC)</td>
</tr>
<tr>
<td>Revolution V</td>
<td>Point the bit</td>
<td>vertical</td>
<td>Negative pulse/RPM</td>
<td>Vertical RSS</td>
</tr>
<tr>
<td>Revolution 16</td>
<td>Point the bit</td>
<td>16</td>
<td>Negative pulse/RPM</td>
<td>High DLS RSS</td>
</tr>
</tbody>
</table>

**Revolution point the bit system**
### Other RSS System

<table>
<thead>
<tr>
<th>Tool name</th>
<th>Steering principle</th>
<th>Max DLS (deg/30m)</th>
<th>Downlink</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>APS Technology RSM Sure-Steer</td>
<td>Push</td>
<td>6</td>
<td>Flow/RPM</td>
<td>RSS within a motor</td>
</tr>
<tr>
<td>Gyrodata WellGuide</td>
<td>Point the bit</td>
<td>3-10</td>
<td>RPM</td>
<td>Cruise control option</td>
</tr>
<tr>
<td>NOV Lateral Drilling Tool LDL</td>
<td>Push the bit</td>
<td>3</td>
<td>RPM</td>
<td>Mechanical controlled</td>
</tr>
<tr>
<td>TerraVici Drilling Solution</td>
<td>Point the bit</td>
<td>12-15</td>
<td>Flow rate</td>
<td>All part rotates (same as SLB’s PowerDrive)</td>
</tr>
</tbody>
</table>
Existing RSS in the market

• APS Sure-Steer 675 Rotary Steerable Motor
Case studies

This section has some SPE case studies removed from original version presented in SPE workshop due to copyright*
Case studies

- Reaching the unreachable!
  - Excess drag
  - Impossible to slide
Rotary Steerable System BHA Increases ROP More Than 25% in Australian Coal Mine
Circulating time decreases 30%, saving Glencore Bulga Underground Operations up to 17 h of rig time
Case studies

• Challenges
  – Very shallow Surface to In Seam (SIS) design
  – Total depth at +/- 3000m
  – Intercept with a vertical well at the toe
  – Reduce drill time from conventional mud motor BHA

• Solutions
  – Utilize RSS (PowerDriveX6 Push the bit system)
  – Combined with LWD (at-bit gamma ray imaging) for geosteering
Case studies

Buckling analysis with mud motor BHA

Axial Load (AL) (lbf)
Single Depth Analysis @ 3200m
Well: SIS 26 Borehole: SIS 26 BHA: SIS 26 Wellbore Geometry
Trajectory: Xstrata-SIS 26 Plan 2.0 BHA: SIS 26 8.5 in Proposed BHA
Mud wt: 9(lbm/gal) DWOB: 15 (1000 lbf) DTOR: 5 (1000 ft.lbf)
Overpull: 0 (1000 lbf) Block wt: 0(1000 lbf)
FF: Slide CH/OH = 0.2/0.25, Rotational CH/OH = 0.2/0.3, Translational FF while
Backreaming CH/OH = 0.05/0.05
Group Scenario: 8.5D Torque & Drag Load Cases 09-Aug-2013 10:12:10

Buckling analysis with RSS BHA

Axial Load (AL) (lbf)
Single Depth Analysis @ 3200m
Well: SIS 34 Borehole: SIS 34 BHA: SIS 34 Wellbore Geometry
Trajectory: Xstrata-SIS 34 Plan 2.0 BHA: PDX6 8.5inch
Mud wt: 9(lbm/gal) DWOB: 15 (1000 lbf) DTOR: 5 (1000 ft.lbf)
Overpull: 0 (1000 lbf) Block wt: 0(1000 lbf)
FF: Slide CH/OH = 0.2/0.25, Rotational CH/OH = 0.2/0.3, Translational FF while
Backreaming CH/OH = 0.05/0.05
Group Scenario: 8.5D Torque & Drag Load Cases 15-Aug-2013 12:57:32
Case studies

- Rate of penetration PDM vs RSS

"With the rotary steerable system, we were able to push the drilling envelope in surface-to-in-seam application beyond 2,000-m MD while maintaining the rate of penetration."

Clint Tadhunter
Manager, Gas Drainage
Glencore Bulga Underground Operations

Images from the iPZIG service were used to place ERD wells in the desired coal seams, and PathFinder passive ranging services were used to intersect existing vertical wells, allowing successful gas drainage.
Case studies

• RSS in CSG environment – Improved efficiency

• CSG wells – 10 well pad
• J-type (Build- hold) with up to 5 deg .30m DLS, 75 deg inclination
• 6 ¾” RSS in 8 ¾” hole size

• Up to 70% more efficiency
Australian Operator Drills 2,400-m Vertical Well with Inclination of 0.75° in Faulted Formation

PowerV RSS enables crucial well evaluation program while saving 2 rig days
Case studies

• Challenges
  – Maintain verticality in highly dip and faulted formation for coring and logging program
  – Observed high build tendency from offset wells

• Solution
  – Automated vertical drilling system PowerV
    • 100% verticality seeking system
    • No input required from surface
    • Maximum WOB applied (not required for control WOB)
Case studies

RESULTS

- Drilled 12½-in section to 2,400-m MD with maximum inclination of 0.75°.
- Drilled 8½-in section to 4,400-m TD with maximum inclination of 0.26°.
- Achieved ROP of 58.2 m/h.
- Maintained verticality to support wireline logging and coring.
- Saved 2 days of drilling as compared with an offset well.

Offset wells 1 and 2 were drilled with mud motor and rotary steerable BHAs, and their wellbores deviated 10–20°. The PowerV RSS maintained verticality in the deep shale reservoir with a deviation of 0.75° or less while maintaining higher ROP than was achieved in either offset well.
What is next for RSS?
What is next for RSS?

• More robust systems to access more challenge targets
• More cost effective - wider applications in high volume markets
• Wired drillpipe – more efficiency in control downhole tools (including RSS) and troubleshooting
Complete auto-drill functionality – Deliver wells remotely from anywhere