Speaker Information

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  • 15 years in engineering, technical, and management roles
  • BS – Computer Engineering
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  • Specialization:
    • Wellbore Surveying
      • Inertial Sensors and Systems
gyroMWD Gross Error Detection

Agenda

- gyroMWD and GyroCompassing Overview
- gyroMWD Gross Error Definitions
- Typical gyroMWD Deployment
- Current Published QC Techniques
- Recommended Additional QC Actions
gyroMWD and Gyrocompassing
Overview

gyroMWD Summary

• At each survey station, the tool is held very still.
• A multiposition gyrocompass survey (independent north finding) is performed

Gyrocompassing

• Gyro sensors measure horizontal direction of earth’s rotation.
• The horizontal direction is used to compute azimuth and gyro toolface

Images: Lawrence, A. (1998)
Properties of Spinning Mass Gyros

Overview

Spinning Mass Gyros
- Floated Rate Integrating SDFG
- Dry Tuned Gyro

Why Spinning Mass?
- Short Acquisition Time, Small Bias, Small Size

Key Error Sources
- Bias(es) (Minimized due to carousel/indexing)
- Noise (Minimized by system design)
- Gravity-Dependent Errors (Mass Unbalance)

<table>
<thead>
<tr>
<th></th>
<th>Mech</th>
<th>Opt</th>
<th>MEMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°C)</td>
<td>150</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td>Shock (g)</td>
<td>2000</td>
<td>3000</td>
<td>4000</td>
</tr>
<tr>
<td>Size (mm)</td>
<td>19</td>
<td>90</td>
<td>25</td>
</tr>
<tr>
<td>S.F. Linearity (ppm)</td>
<td>70</td>
<td>500</td>
<td>100</td>
</tr>
<tr>
<td>G-Dependent Error (*/hr/G)</td>
<td>0.5</td>
<td>0</td>
<td>0.1</td>
</tr>
<tr>
<td>Bias (*/hr)</td>
<td>0.1</td>
<td>0.1</td>
<td>10</td>
</tr>
<tr>
<td>Acquisition Time (s)</td>
<td>100</td>
<td>500</td>
<td>10</td>
</tr>
</tbody>
</table>

Images adapted from: Lawrence, A. (1998)
Updated from: SPE 63274
Typical gyroMWD Deployment

Top Hole – Under the Platform
- Other wells are very close, right from the start
- Greatest collision risk may occur right away
- Well plans are low angle, and often have minimal azimuthal variation

Start by Drilling Cement
- Drilling cement is rough
- If drilling out of a batch-set conductor, it can be even harder.
- Gyro tools are sensitive to shocks and vibrations.

Floating and Riserless
- Surface movement can cause significant noise on the downhole gyro, which adds to other challenges
Description:
Computed horizontal earth rate is compared to theoretical value for job latitude.

Limitations for Typical gyroMWD Runs:

- Errors in MUI/MUQ are undetectable using the HERT when drilling North/South
  \[ \Delta A_{MUI} \approx \Delta MUI \cos(Az) \sin(I) , \ \Delta ER_{MUS} \approx \Delta MUS \sin(Az) \sin(I) \]

- Errors in MUS/MUS are undetectable using the HERT when drilling East/West
  \[ \Delta A_{MUS} \approx \Delta MUS \sin(Az) \tan(I) , \ \Delta ER_{MUS} \approx \Delta MUS \cos(Az) \tan(I) \]
Description:
Multistation tests utilize survey data collected from multiple survey points to test critical error sources.

Limitations for Typical gyroMWD Runs:
- Safety-critical risks often exist at start of run
- Simple well trajectories limit observability of key error parameters
- Drilling may cause damage to the gyro, reducing efficacy of small MSA sets.
Current Gyrocompass QC Techniques
Kinetic Noise Detection

Description:
Detection of gyro saturation or noise triggers extended surveying times at potential lower sensitivity. May also trigger repeat surveys.

Limitations for Typical gyroMWD Runs:
• Difficult to characterize noise input and determine uncertainty
• Catastrophic gyro failure may emulate Kinetic Noise situations

ERH = 7.5 deg/hr
    = 0.0021 deg/s
Movement must be < 0.001 deg/s!
Safety-Critical Close Approaches

Suggested Additional QC Actions

Use Existing Benchmark Surveys

• In wellbores with established (and surveyed) inclinations, pull back to known benchmarks to compare surveys

Establish New Benchmark Surveys

• Use independent survey instrument (e.g., wireline)

Use Conservative Error Model

• When benchmarks are not available
• Accounts for potential gross error

Modification of well plans or survey programs

• Accommodate additional benchmark options.
• Establish an azimuth early which can be used for later benchmarks

Comparison of gyro surveys against available data

• Magnetic
• Projected trajectory

Table 2. Gyro to Gyro Allowable Tolerance

<table>
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<tr>
<th>Allowable Gyro to Gyro Tolerance at Same Survey Depth</th>
<th>Inclination Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inclination</td>
<td>±0.25°</td>
</tr>
<tr>
<td>Azimuth</td>
<td>±5°</td>
</tr>
<tr>
<td>Azimuth</td>
<td>±3°</td>
</tr>
<tr>
<td>Azimuth</td>
<td>±4°</td>
</tr>
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Table 3. Gyro to Magnetic Allowable Tolerance

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Note!

All of these challenges and techniques apply equally to magnetic MWD data – limitations of single-station QC, insufficient variability in wellbore trajectory to observe sensor errors, and potential for variability during a run due to drilling damage.

Magnetic MWD systems, however, are typically used in well sections where geometric separation to offsets is significantly larger than top hole sections where gyros are used.

So for magnetic MWD systems, while gross errors can happen, they do not usually result in unexpected safety-critical close approaches, but rather just unpleasant deviation from plan.