Gross Error Detection for Typical gyroMWD Operations

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Speaker Information

- Ben Hawkinson
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  - 15 years in engineering, technical, and management roles
  - BS – Computer Engineering
  - Paso Robles, California
  - Specialization:
    - Wellbore Surveying
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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

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

Updated from: SPE 63274

Spinning Mass Gyros

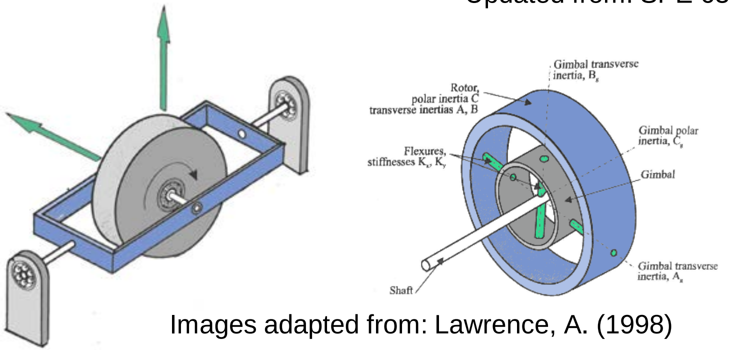
- Floated Rate Integrating SDFG
- Dry Tuned Gyro

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



Images adapted from: Lawrence, A. (1998)

Typical gyroMWD Deployment

Top Hole – Under the Platform

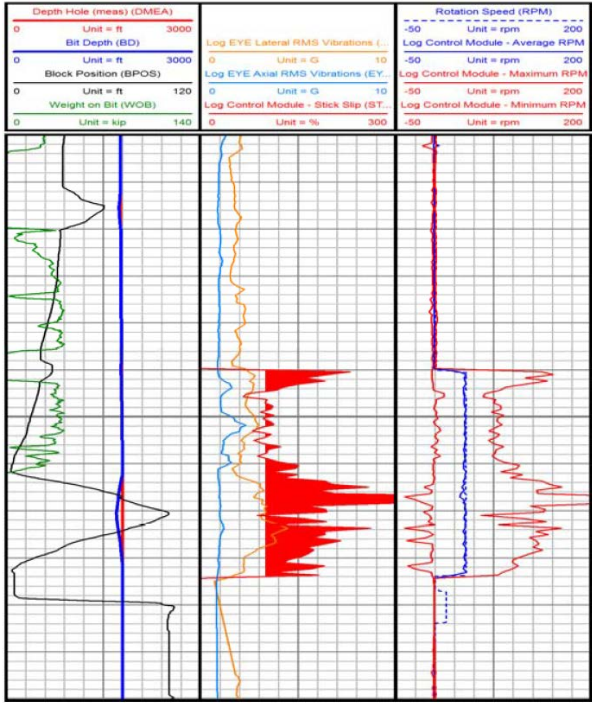
- Other wells are very close, right from the start
- Greatest collision risk may occur right away
- Well plans are low angle, and often have minimal azimuthal variation

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



Current Gyrocompass QC Techniques
Horizontal Earth Rate Test (HERT) (SPE 103734, 90408)

Description:

Computed horizontal earth rate is compared to theoretical value for job latitude.

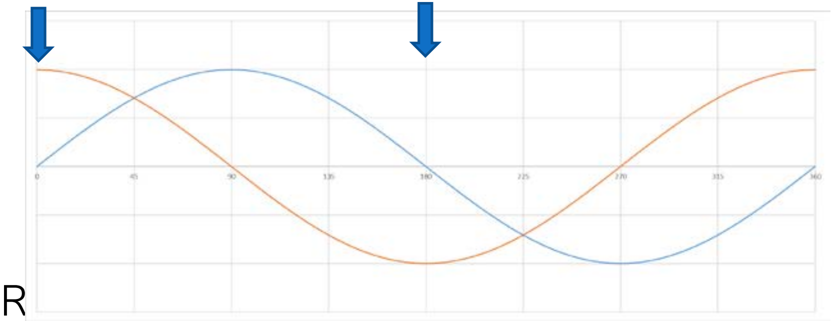
Limitations for Typical gyroMWD Runs:

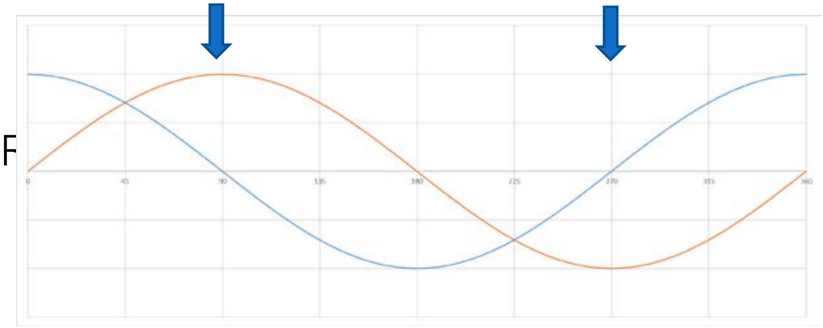
- Errors in MUI/MUQ are undetectable using the HER when drilling North/South

$$\Delta Az_{MUI} \approx \Delta MUI \cos(Az) \sin(I) \quad , \quad \Delta ERH_{MUS} \approx \Delta MUS \sin(Az) \sin(I)$$

- Errors in MUS/MUS are undetectable using the HER when drilling East/West

$$\Delta Az_{MUS} \approx \Delta MUS \sin(Az) \tan(I) \quad , \quad \Delta ERH_{MUS} \approx \Delta MUS \cos(Az) \tan(I)$$





Current Gyrocompass QC Techniques
Multi-Station Gyro Test (MSGT) (SPE 103734)

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.

Measured Depth (m)	Inclination (°)	Azimuth (°)
600.00	8.382	166.638
630.00	8.799	172.728
660.00	9.304	178.217
670.53	9.500	180.000
690.00	10.149	180.000
720.00	11.149	180.000
750.00	12.149	180.000
780.00	13.149	180.000
810.00	14.149	180.000
815.00	14.316	180.000

ISCWSA

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!

ISCWSA

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 (eg 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

Allowable Gyro to Gyro Tolerance at Same Survey Depth		*Inclination Range*
Inclination	*±0.25°*	*0-40°*
Azimuth	*±5°*	*1-5°*
Azimuth	*±3°*	*5-20°*
Azimuth	*±4°*	*20-40°*

Table 3. Gyro to Magnetic Allowable Tolerance

Allowable Gyro to Magnetic Tolerance at Same Survey Depth		*Inclination Range*
Inclination	*±0.25°*	*0-40°*
Azimuth	*±5°*	*1-5°*
Azimuth	*±3°*	*5-20°*
Azimuth	*±4°*	*>20°*

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.