SPE 140192

Improving the Quality of Ellipse of Uncertainty Calculations in Gyro Surveys to Reduce the Risk of Hazardous Events like Blowouts or Missing Potential Production through Incorrect Wellbore Placement

Roger Ekseth, John Weston, Adrián Ledroz, Barry Smart, Astrid Ekseth – Gyrodata

2011 SPE/IADC Drilling Conference and Exhibition
Amsterdam, The Netherlands.

Introduction

- SPE 67616 by Williamson outlines the mathematical framework and numerical inputs for MWD surveys error model.
  - MWD sensor performance is somewhat similar
  - Magnetic field distortions and fluctuations are the main source of errors.

- SPE 90408 by Torkildsen outlines only the mathematical framework gyro survey tools.
  - Gyro sensor performance greatly varies between companies.
  - Earth Rotation rate is a very stable reference, main source of error is related to the sensor performance.

Objectives

- To start a process to close a potential safety gap associated with "unproven gyroscopic error models"
- To present the derivation of a set of realistic uncertainty estimates for gyroscopic tools based on statistical analyses of real downhole data
- To emphasize the fundamental issue of linking error models with QC procedures

Layout and Scope

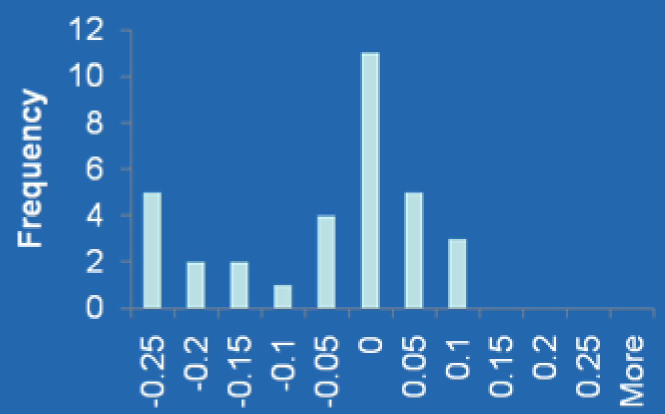
- Assumption: survey data is free of gross error, data outside ± 3σ confidence (QC) level are excluded.
- Services to be analyzed:
  - Stationary surveys
    - Multistation gyrocompassing on wireline
    - Multistation gyrocompassing with battery tools dropped into the well
  - Continuous surveys
    - Continuous survey on wireline in deviated wells
    - Continuous survey on wireline in vertical wells
- Kick-off and orientations and GWD are not included in this study

Layout and Scope II

- The creation of dedicated error models dependent on:
  - Sensors used
  - Sensor configuration
  - Running gear – centralization of the tool
  - Running procedure
  - Tubular – drillpipe, casing, conductor, tubing
  - Environmental conditions – type of rig
  - Quality Control
  - Correction procedures adopted

Preliminary Statistical Analysis

- 484 surveys from different regions were analyzed.
- Probability distribution was estimated for each error source.
- Distributions were classified as Normal (Gaussian) or not-Normal.



- 3σ level QC was used for Normal distribution and 2σ level QC was used for not-Normal distribution

Estimation of Uncertainty Parameters

- Accelerometer, gyroscope and environmental errors are examined separately for stationary and continuous surveys services
- Sensor performance and QC are based on:
  - Multi-Station Correction (MSC)
  - Tool Repeatability
  - Inrun / Outrun comparison
- Stationary surveys:
  - MSC based on the physical model of the sensors
- Continuous surveys:
  - Empirical model of the tool behavior

Accelerometer Errors I

- Z-indexing three-axis accelerometer system were analyzed.
- G-total test of downhole data provided information about the accelerometers performance.
- Z-indexing eliminates X and Y bias errors.
- Z-accel bias is the dominant source of error – standard deviation of the mean gravity error is a good estimate of the Z accelerometer bias uncertainty.

$$ABZ = \sqrt{\frac{\sum GE_i^2}{n}}$$

Accelerometer Errors II

- Accelerometer random error (RA) is introduced to overcome QC issues at certain orientations.
- RA can be calculated as follows:

$$RA = \sqrt{\frac{\sum \sigma GE_i^2}{n} \cdot C_e}$$

- ABX, ABY and ABZ propagate randomly with weighting functions according to the gyro EM paper.
- Continuous accelerometer measurements.
  - Uncertainties modeled as for stationary surveys.

Gyro Errors – Stationary I

- Company Standard Practices:
- Z-axis indexing of XY gyro.
- MSC:
  - Multistation correction algorithm based on XY gyro model and Earth Rate has been implemented.
  - Apparent gyro bias errors (*GBX* and *GBY*), the direct mass unbalance error (*M*) and the random gyro noise (*RG*) can be estimated.
  - Correlation coefficients (CC) based on well geometry and running configuration must be checked.
- Pre and post job field Roll Test (RT)
- Pre and post job base RT

Gyro Errors – Stationary II

```
Residual Noise in deg/hr
  StDev     Tolerance
  0.079     0.221
Systematic gyro error corrections in deg/hr
    dgx       dgy       dmbo
 -0.162     0.012     0.146
StDevs
  0.008     0.008     0.009
Tolerances
  0.033     0.033     0.087
Correlation coefficients for gyro errors
              dgx       dgy       dmbo
dgx         1.000     0.044     0.070
dgy         0.044     1.000     0.026
dmbo        0.070     0.026     1.000
Min/max correlation coefficient:  0.07   Tolerance: +/- 0.42
```

$$GB_{co} = \sqrt{\frac{\sum \sigma BX_i^2 + \sum \sigma BY_i^2}{2n}}$$

$$GB_{uc} = \sqrt{\frac{\sum GBX_i^2 + \sum GBY_i^2}{2n}}$$

$$M_{co} = \sqrt{\frac{\sum \sigma M_i^2}{n}}$$

$$M_{uc} = \sqrt{\frac{\sum M_i^2}{n}}$$

$$RG = \sqrt{\frac{\sum \sigma RG_i^2}{n}}$$

Gyro Errors – Stationary III

- Corrected model:
  - EM is based on downhole data and MSC uncertainty values
  - QC is based on downhole data only

- Uncorrected model:
  - EM is based on downhole data and MSC systematic correction
  - QC is based tool repeatability (RT)

Gyro Errors – Continuous I

- Empirical model is used – Error contributions include: initialization error, linear drift and random walk.
- Initialization is obtained through gyrocompass.
- Inrun-outrun based azimuth drift correction algorithm is used to correct the data.
  - The algorithm reports the average inrun-outrun drift and the associated random walk. This parameters can be analyzed and used for an uncorrected model.

$$LD_{uc} = \sqrt{\frac{\sum LD_i^2}{n}}$$

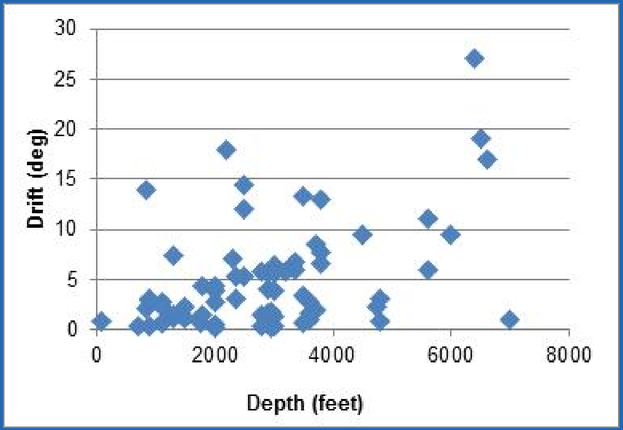
$$RW_{uc} = \sqrt{\frac{\sum RW_i^2}{n}}$$

Gyro Errors – Continuous II

- Linear drift correction does not only remove linear drift, but also part of the random walk drift.
- Effect of the linear correction was study through analysis of artificially generated data.
- Semi-random wells with semi-random surveys data were generated and processed with the drift correction routine.
- $LD_{co} = 0.23 \cdot LD_{uc}$
- $RW_{co} = 0.49 \cdot RW_{uc}$

Gyro Errors – Vertical Continuous

- Empirical model approach – Error contributions include: initialization error, linear drift and random walk.
- Issues:
  - Z-axis gyro is use to track gyro toolface.
  - At low INC, AZH and INC are highly correlated.
  - Drift on gyro toolface is not proportional to depth



Gyro Errors – Vertical Continuous II

- Proposed alternative: Link sensor performance with QC through the use of Coordinate different test (CDT).
- Gross Errors and systematic errors are controlled through single station test (GC) and drifts checks (VC)
- Random errors are controlled through CDT
- North and East errors give rise to a circular error in the horizontal plane and it is modeled as:

$0.003 \cos(azimuth) \cdot \sqrt{(depth)}$ for North

$0.003 \sin(azimuth) \cdot \sqrt{(depth)}$ for East

Tool Misalignment

- Tool misalignment are estimated through inrun/outrun misalignment test for continuous runs.

- Test is based on inclination differences at taken depths

$$MX = MY = \sqrt{\frac{\sum MX_i^2 + \sum MY_i^2}{2n}}$$

- Misalignment for drop surveys is not included

Conclusions

- There is a vital need for representative and justifiable error model for safe and reliable surveying when using gyroscopic tools.
- The paper illustrates the procedures adopted by one gyro service company for the extraction of realistic error model data - new set of uncertainty estimates for some existing gyroscopic tools.
- Individual service companies can and should provide error models based on real downhole data for each type of tool and service on offer.
- Substantial effort and resource commitment are needed to generate error models

Closing remark

Continued use of unproven or overly optimistic error model inputs for gyroscopic tools might lead to hazardous events or missed targets