38th Meeting of the SPE Technical Section on Wellbore Surveying

Presentation #1: Borehole Drift: Effect of Continuous Surveys on Wellbore Curvature & Torsion

(Robello Samuel)

- Discussed basic well shapes and assumptions. Pre-determined shapes between survey intervals. Is this enough? Different methods of wellbore propagation yield different results.
- Discussed different drilling difficulty indices. Focused on wellbore torsion and direction of bi-normal vector calculated from continuous surveys. Can use curvature and torsion to calculate elastic strain energy of a wellpath.
- Looking at torsion in addition to curvature can help explain events such as stuck pipe in a low curvature section (that has a high twist). Can also help more accurately predict hook load, drag, side force, and other quantities (assuming the planned well shape is analyzed or dense/continuous surveys are used).
- Wellbore curvature and torsion at survey stations well define the shape of a wellbore within a survey interval.

(Questions)

- Pete Clark – Have you looked at slide/rotate actual data? Answer - Yes, we have analyzed different slide/rotate scenarios. There is a plan to present this data in the future. Pete – This tool can predict where you are more likely to get stuck?
- Stefan Maus – What difference do you get between minimum curvature and new torsion-based method for wellbore position. Answer – Shape is determined using a spline, so there is a difference. Sometimes the differences get averaged out. Also dependent on the survey spacing.

Presentation #2: Automatic Magnetic Observatory for Drilling Assistance

(Alexandre Gonsette)

- Magnetic field is composed of main field, crustal anomalies, and diurnal effect. Daily variation up to 600 nT in field intensity, 0.5 degrees in inclination, and 2 degrees in declination at high latitudes. Even more during large magnetic storms.
- Field strength is usually measured robustly with proton magnetometers. Theodolites used to determine dip and declination (complicated procedure to compensate for errors).
- Can accomplish vector field monitoring using a variometer (measures changes relative to baseline).
- As an alternative, can use AutoDIF (automates theodolite procedure). Can take up to 6 measurements per hour with an accuracy < 0.01 degree. Can also operate as a variometer with same accuracy. Output data compared with manual theodolite data and compared well.
- The north target is problematic: requires a long distance (300 ft), must remain stationary (problem in frozen areas). This has been addressed by adding a fiber optic gyro (FOG) as a

North-seeker. Gyroscope used is KVH DSP 1750 single axis gyro (0.05 deg/hr bias stability). Better specifications provided by Emcore Emp 1.2k (0.005 deg/hr bias stability), but this requires a special license.

- First generation North-seeker prototype is promising (1 hour per magnetic vector observation).

(Questions)

- Bill Allen – How much time does it take to measure the magnetic field vector with each system? Answer – North seeker takes 1 hour because gyro must spend 5 minutes in each of 8 positions
- Gerard w/ Shell – How far away can you be from the baseline equipment to ensure valid variometer measurements. Answer – Can be very far away; we use a single baseline for all of Holland. Of course it depends on desired accuracy. Gerard – Would you need to set up a base station offshore if you have one within xx miles? Answer – Yes, it should be ok depending on what accuracy you want.
- ?? – This is a solution that can come very close to your station to alleviate problems associated with being far from an observatory.

Sub-Committee Update: Error Models

(Steve Grindrod)

- Worked on Operator Wellbore Survey Group error models. Deliverables will be standard sets of error models that are self-documenting. Three files: fixed rig, floating rig, and combined Compass IPM. Also plan to have diagnostic files.
- There are 5 OWSG sets. OWSG Standard Set (Set A) is the set that contains about 80% of the error models that anyone would want to use. This set currently contains 34 models. Nine generic gyro models will be replaced by 3 models (should be using contractor-supplied models with gyros). Inclination only model to be moved from Set B to Set A. MWD+IFR1+MS to be added. So new Set A will have 30 error models.
- Changes:
    - Using MWD toolface independent model
    - Drillstring magnetization (AMID) being replaced by AMIL (in nT).
    - Misalignment being increased from 0.06 degrees to 0.1 degrees.
- To do:
    - Update header to include latitude range and verification level
    - Delete drillstring magnetization constant term (AMIC)
    - Add term comment on singularities
    - Change inclination-only tool limits
- Models will be summarized in upcoming SPE paper: SPE 167964.
- New file prefixes and error model naming conventions were detailed
- IFR1 is crustal correction and IFR2 is IIFR.
- Floating rigs have _Fl appended to the end of the error model name; Fixed rigs have no specific annotation at the end.

(Questions)

- Son Pham – Simon McCulloch donated a data set for this work. Steve and Ann Holmes have been …
- John Barlow – What is the communication method for release? Answer – They'll be on the ISCWSA website. Final format may change yet from Excel.
- Pete Clark – We want a consistent approach for collision avoidance across businesses. We view a consistent set of error models as a necessary step toward that.
- Bill Allen – These error models will be loaded on the ISCWSA website. There used to be a statement from the ISCWSA that we don't have models, but now we can't say that. Do we need to have a check to verify the error model being used is actually the one posted on the website? Answer – Use the check sum value.
- Roger G. – How will older wells be updated? Answer – That's a major challenge. There's a tool in Compass to do a global replace, but you probably want a database expert to help so you don't corrupt your database. Do this carefully because this is safety critical data.
- Doug Gilmour – Do we have a new set of standard wellbores against which to test these? Answer – We're using the 3 standard wellbores from the MWD paper.

Presentation #4: Automated Look Ahead Clearances

(Carol Mann)

- We want to raise awareness of good practices in collision avoidance. Even with awareness, the human factor remains. Various studies have attributed 90% of accidents to human error to one degree or another. Automation helps to ensure anti-collision calculations are always run.
- Automated look ahead clearance calculations run automatically in the background on an extension of the well, and run the chosen anti-collision calculations.
- There is an automatic alert that triggers action by the user in the event anti-collision rules will be violated.

(Questions)

- Bill Allen – You raised the human element. Can you take the human element out of the activity you just showed, by WITSML or some other method? Answer – We've talked about it, but haven't gotten to that point yet. We're still evaluating the current process that was put out a year ago.
- Pete Clark – This is very valuable. I've met several directional drillers that don't do anti-collision calculations, so I think this has great value from a safety standpoint.
- Andy Kauffman – You have to be careful with your look ahead/prediction. It's somewhat iterative with the DD. It's difficult to predict what the DD is going to do next, and a lot of people will believe what the computers tell them, even if it's not accurate. Answer – We are trying to

keep the solution simple, rather than overly clever. We want to nudge people and make them proactive. We also kept the distance short (only 3 stands) for this reason.

- Bill Allen – You've had this in place about a year. Have you changed it much? What has the feedback been? Answer – It really didn't start getting into the field until April or May of this year. Some people really hate it while others think it's exactly what they need. I haven't gotten feedback that indicates we need to change it, but the feedback is still preliminary. Bill – I strongly discourage the use of 2 rules for anti-collision. Have you gotten feedback on the ability to use 2 rules? Answer – No, not yet.
- Gustavo ?? – Bill, in your opinion, does the anti-collision calculation need to occur in the office? Bill Allen – I think the DD should do as little re-planning as possible. We want things to not add burden to the DD. Do as much up front as you can in the office.
- Steve Sawaryn – I like the direction this is going. Have you thought about bringing the calculations back into the planning stage? The guy on the rig needs the envelop in which he is expected to remain. Answer – We're about to release minimum allowable separation tubes in 3D, which will be available during planning.
- Roger G. - We've recently automated the traveling cylinder plot and synced some screens between the office and the rig. We've also automated text alerts.

Sub-Committee Update: Collision Avoidance

(Steve Sawaryn)

- Covered previous deliverables of the group over the last 5 to 6 years (lexicon, bibliography, current common practice, etc…)
- Now moving into a consolidation activity. The goal is to finalize the document set by March of 2014. Also want to implement a sustainability program and come up with high-level collision avoidance requirements (based on previous documents).
- By March 2014:
    - Comparison of different collision avoidance methods (first step toward a unified collision avoidance rule).
    - When business partner does collision avoidance scan, assurance that the separation factor is acceptably similar. Requires a test framework.
    - General expectation for collision avoidance process (document).
    - What is the standard content (and format?) for a collision avoidance report?

(Questions)

- Carol Mann – Will there be a movement within the operators' group to include collision scans over more paths? Answer – First we need to get the big picture to figure out what we've got. Pete Clark – The answer is yes. There is a set of 11 well plans (or so) that were created to provide a test data set for collision avoidance and position uncertainty calculations. One of the uses would be to test the similarity of separation factors between different anti-collision calculations.

Presentation #5: Axial Magnetic Interference Terms

(Harry Wilson)

- This relates to the behavior of the drill string interference terms in the ISCWSA error models. This is one of two dominant error source for Azimuth (next to declination uncertainty). Drill string interference currently has two error model terms associated with it.
- Gave a tutorial on the measurement of azimuth via magnetometers and the corrupting effect of drill string axial magnetic interference.
- Also discussed induced magnetic interference due to the presence of the drill string in the Earth magnetic field. Maximum effect of induced magnetic interference on azimuth is at some intermediate angle between the magnetic field vector and 90 degrees perpendicular to said vector.
- The two current axial magnetic interference terms are AMID (direction-dependent) and AMIF (fixed value). These terms do not model induced axial magnetic interference. The fixed component is somewhat contentious, but there was a good reason for its implementation. However, this term is inconsistent with what should occur at vertical or North-South. There should be no azimuth effect due to drill string interference at these orientations. These terms must be evaluated for each BHA. AMID can also be treated as a bias of 0.33 degrees, with reduced uncertainty to 0.5 degrees (no longer recommended by the ISCWSA Error Model Sub-Committee).
- The compliance of the BHA with the model must be done pre-job and while drilling (Bt and Dip QC tests). The Bt and Dip QC tests must use interference values in nT that are equivalent to the error model terms, which are specified in degrees. The maximum allowable Bz uncertainty is what is fed into the QC tests. At low inclinations, this max. allowable Bz limit is very large (due to the AMIF term), which makes the QC test very insensitive.
- Note that the uncertainty prediction due to AMID and AMIF is not location-dependent; due to this, the spacing requirement is location dependent.
- An alternative is to replace AMID/AMIF with AMIBZ (or AMIL on the OSWG models), which is specified as a Bz bias effect in nT. A value of 150 nT is still arbitrary, but is a good match for the AMID/AMIF terms at North Sea latitudes). This method prevents the loss of sensitivity in the QC tests.

(Questions)

- Neil Bergstrom – What did you use for the assumptions? The usual thing is to assume the magnetism of the drill string components. Answer – The presentation was independent of that, but you are right. We assumed that each piece of steel is a dipole, with an equal-but-opposite pole on each side. Our (BHI) algorithm is just a rough estimation tool to ensure we fit within our error models and don't trip QC tests. We are not making corrections based on this tool.
- Lisa Grant – How do you specify your magnetic spacing requirements when you are doing MSA or single station correction? Answer – Single station correction is only concerned with enough spacing to mitigate misalignment effects since the z-axis is not used (3 to 4 meters spacing).

This keeps x and y isolated from z. When we use MSA, we typically don't correct; it's primarily used as a QC tool.

- Neil Bergstrom – Regarding remnant magnetism vs. induced magnetism, I think remnant magnetism is 90% of the problem. Also, these terms should be random (not biased), because this effect is primarily from magnetic particle inspection, which yields random results. Also, there are standards that could be enforced.
- Bill Allen – Sometimes the QA/QC windows we generate before drilling a well are crude. Could the tool you showed be used to plan QC/survey programs over the well? Answer – Yes, that is how the tool is used.

Sub-Committee Update: Well Intercept

(Ross Lowdon)

- Finalized the well intercept outline.
- Defined a portion of the ranging lexicon. Could potentially add to/use the SLB oilfield glossary.
- NEW CHAIRPERSON: Mike Long
- Relief well planning (discussed Oil and Gas UK, which has guidelines, but costs $; could potentially contribute to these guidelines.).
- Future work: finish lexicon and relief well guidelines.
- Membership will be put up on the website.

(Questions)

- Bill Allen – We should perhaps post the membership of all sub-committees on the website.

Presentation #6: Using Core Flow to Forecast the Short-Term Change of the Magnetic Field

(Ciaran Beggan)

- The core of the Earth is about 90% Iron with a temperature of > 3500 K. Freezing of the inner core repels light elements.
- A conductive fluid in motion within a magnetic field creates electric currents. These electric currents generate a secondary magnetic field, which is what we see at the surface. Requires about 4 GWatts to generate.
- If we assume that the magnetic field is frozen into the fluid, we can infer the flow from the change of the magnetic field. Solve for flow and the rate of change of the flow (subject to several assumptions). We can create models of the flow and use it to predict the flow into the future.
- This method assumes flow and acceleration are steady. It will not capture rapid changes in the flow (no method will).

- The mean velocity of the flow is approx. 14 km/yr.
- Can check flow models against past data or observatory data.
- The IGRF-11 and CHAOS-4 models are some current geomagnetic models. The BGGM was compared against these two models. The CHAOS-4 data matches BGGM best since they are both based on satellite data.
- Compared flow model prediction to the three models mentioned. Matched well at three different observatories in the Northern Hemisphere. Southern Hemisphere was also examined.
- New model had best prediction capability based on observatory data, by an average improvement of 10%. This is believed to be due to the flow acceleration term, which will subsequently be included in BGGM-12.
- ESA SWARM launches in 2014 (satellite mission). Separate core, crust, and external field. Three satellites. Vector data will be available three months after launch, but full calibration will take longer.
- As part of the SWARM method, there is a push to get observatories to post next-day data within 5 nT of later definitive data. Led by INTERMAGNET.

(Questions)

- Stefan Maus – I think this is a great idea, but as you pointed out there are significant ambiguities such as different flows that generate the same magnetic fields. Have you looked at that? Answer – Yes we have looked at different types of flows. These steady flows, which are kind of averages, tend to produce the best results over short periods.
- Robert Wylie – Are flows of 14 km/yr relative to a fixed point in the crust? Answer – Yes.
- Ross Lowdon – The SWARM satellites. What kind of resolution are you expecting? Answer – Two satellites will fly side-by-side to get a gradient effect. They are looking to get models to degree 150; possibly up to degree 250. Ross – Are you going to use aero-magnetic data to test? Answer – You're still on a different scale. That scale gap needs to be filled in order to do that. It probably won't be directly comparable to aero-magnetic surveys.

Presentation #7: Distribution of real survey errors effecting wellbore collision probabilities

(Torgeir Torkildsen)

- Must account for nature of probability distribution when making collision probability calculations. The probability distribution is usually illustrated by concentric ellipses.
- The collision probability is the pdf integrated over the appropriate area/volume. (Several examples of relative wellbore geometry were given.)
- Collision probabilities depend on relative position accuracies, probability distribution functions (pdf), and/or cumulative probabilities.
- Normal distributions are usually assumed. A bibliography was presented for an analysis of the pdf of empirical data. The empirical data does not match the normal distribution at larger

distances. An alternate distribution was presented that better matches the empirical data (attributed to Hugh Williamson).
- Conclusion: If collision probability matters, you should take into account the real distributions.

(Questions)

- Harry Wilson – The breakout point where the actual distribution exceeded the normal distribution looked to be at about the 3 sigma point, so we like to think our QC tests are bounding the problem. Answer – This is a good point, but just like our Bt and Dip QC tests, there will be some cases you don't catch.
- Harry Wilson – Extending the argument, this may be one way of quantifying the argument of extremely rigorous QC.
- Neil Bergstrom – This validates what I have seen looking at errors. It's interesting that the curve crossed over at 2 sigma. Outside of that, you could be anywhere.
- Pete Clark – At the previous meeting in Paris, Bjorn and Erik presented on the Chi-square distribution, which pointed out that we should be having more collisions that predicted by the normal distribution. This presentation seems to validate that.

Presentation #8: Survey Analysis: A Graphical Method to Determine Magnetic Reference Values

(Stuart Sargeant / Jeremy Strugnell)

- What if scenarios: tool calibration and or bias errors. Model survey data under these scenarios.
- Graphically plot calculated data to identify MWD problems.
- An iterative method of identifying out of spec error source and correction was presented. X and Y biases result in a sinusoid in the total field value vs. toolface angle.
- Z-axis magnetic biases from different runs can be corrected based on graphical analysis.
- The tool presented was called a Do-It-Yourself (DIY) correction technique.

(Questions)

- Bill Allen – To the layman it might appear you're just finding numbers that work, rather than finding potential error sources. Answer – For this case, dip was off by 2.5 degrees. If that's the case, you need to find the source of that offset. The Bt and Dip tests provide a check on the accuracy of the corrections.
- Andy Brooks – This looks like a manual multi-station analysis. Is that a good assumption? Answer – Not exactly. It's more exercising what if scenarios. Andy – An MSA concern is that you need to have enough curvature in the hole. Also what error model are you applying to the corrected data? Answer – A large attitude variation is desirable.
- Neil Bergstrom – This is essentially the same method I use to deal with data. Almost all wells have a build section that changes direction. The measured reference values should be constant through this hole section.

Sub-Committee Update: Operator Wellbore Survey Group

(Neil Bergstrom)

- Agreed upon a mission statement: To promote practices that provide confidence that reported wellbore positions are within their stated uncertainties.
- Membership: 46 individual members on the mailing list.
- Next meeting planned for November 14th.
- Current initiatives:
    - Format for reporting and transmission of raw sensor data (OGP is working on an update of their P7 format to include raw MWD data; want to stay in sync with OGP on this).
    - OWSG standard set of error models.
    - Recommendations for good practice (summarized in presentation).
- Proposed initiatives:
    - Standardization of MWD QC requirements.
    - Minimum operating and reporting procedures.
    - Directional and/or anti-collision software test suite (methodologies for validating different approaches).
- Recommendations for good wellbore surveying practices were presented (see presentation).
- Operators really want the raw sensor data, but not always needed in real-time.
- Slide sheets are considered part of the wellbore record.
- Some minimum reporting requirements were also discussed (see presentation).
    - Would like a plot of the QC parameters for each BHA run, including the applied limits.
- Survey operating recommendations were presented (see presentation).
- Magnetic inspection standards for BHA components should be met (with proof).

(Questions)

- John Thorogood – I haven't heard anything today about errors in depth. Answer – I agree that's important. It should be easy to eliminate gross errors by counting in an automated way when they are put down hole.
- Harry Wilson – The ambitions are laudable, but in some markets it can be a struggle to get people to do things right, but part of that is the operators in those regions don't demand it. This can also mean a change to the business model in certain areas. The current business model is based on current practice, which is not what we want. Answer – I agree. Pete Clark mentioned some of these things may have more impact as an ISCWSA recommendation. Lisa Grant – Your right. Part of the issue is about education. This is also a reserves issue, and maybe that is what needs to be stressed, especially when tight placement is necessary.

Election of New Officer: Program Chair

(Bill Allen)

NEW CHAIRMAN: Pete Clark

Candidates for Program Chair: Ross Lowdon and Son Pham.

NEW PROGRAM CHAIR: Son Pham

Treasurer's Report

(Robert Wylie)

- Current balance of around $55k (see presentation for details).
- New process for approving expenditures was presented. This will become part of the section constitution.

Sub-Committee Update: Education

(Steve Mullin)

- There's a possible $25k expenditure on the e-book (although a new quote has been requested).
- Two new chapters were added to the e-book (funded by Shell):
    - Subsea positioning
    - Relief well drilling
- The hits and misses workshop from last year is being repeated in Denver the first week of November.
- Looking at doing more workshops in the future. Conversations with the drilling automation group about doing a combined workshop in the future. Another concept is to try to bring engineers and geoscientists together in a manageable way.
- Intend to continue doing topical lunches. Have booked one for ATCE next year. Looking at doing one at the unconventional resources conference next summer in Denver.
- Trying to get something into JPT to spread the word to the general industry more.
- Definite need for wellbore positioning education in Dubai. Conversation started regarding this topic.

Update from Webmaster

(Phil Harbidge)

- The section website is www.iscwsa.net (the www.iscwsa.org website is run by Steve Grindrod). There is also a site on for the technical section on the SPE website; however, this website is restricted to SPE members.
- Send suggestions for improvements to Phil.

- It might be possible to standardize any PowerPoint and documents with a specific header/background/format.

Next Meeting Suggestions:

- Ft. Worth, TX
- Kuala Lumpur (potential operator sponsor; see Phil Harbidge)
- Northern California (Scientific Drilling sponsor)

Note: The presentation **"Magnetic observatory data, and how it is collected"** by Tim White was cancelled due to the US government shutdown.