geoconvention
Calgary · Canada · May 12-14 2025

Optimizing Azimuth Positions: Smart Simulation for Wellbore Trajectory Design

Author information – Dr. Darlington Etaje. Udeobi O. Jennifer
Affiliation – University of Calgary

Summary

This study presents a novel approach for reverse engineering well paths by leveraging the principle that azimuthal transitions follow the shortest possible path to the subsequent target, relative to the current trajectory. Utilizing randomly generated Measured Depth, Inclination, and Azimuth (MIA) values for six pay zones and incorporating various trajectory types (Turn, Drop, Build, Build & Turn, Drop & Turn, and Straight), By employing the Minimum Curvature Method (MCM) within a MATLAB framework, the resultant Northing, Easting, and True Vertical Depth (NET) coordinates were accurately calculated. Analysis of the resultant Northing vs. Easting plot reveals that azimuthal changes are curvilinear, not linear, and that subsequent azimuth positions are consistently located either to the left or right of the current trajectory. This observation allows for accurate prediction of azimuth for each pay zone, which can significantly improve well path optimization and reduce drilling errors.

Theory

The Minimum Curvature Method (MCM), while effective, has notable limitations in highly deviated or extended well paths. These arise from its reliance on linear approximations and a static reference point, such as the Kick-Off Point (KOP). As drilling progresses, the wellbore's continuously changing orientation is not fully accounted for, leading to positional inaccuracies over long distances or in complex trajectories.

To overcome these challenges, this study proposes a dynamic approach that adjusts the reference frame in real time to align with the wellbore's current azimuth. By shifting the reference frame dynamically rather than relying on a fixed origin, the method more accurately captures the curvilinear nature of the well path. This enhancement ensures precise well placement, minimizes deviation from the true trajectory, and improves drilling efficiency, especially in highly deviated and horizontal wells.

The process of simulating a well trajectory begins first by establishing an initial reference point. This was set at surface co-ordinates, (0,0,0). Randomly generated values for MIA were assigned to the Kick-Off Point (KOP) and the five pay zones to define the trajectory. These values were carefully selected to represent various trajectory types, including:

- ✓ **Turn Only:** Azimuth changes, inclination remains constant.
- ✓ **Drop Only:** Inclination decreases, azimuth remains constant.
- ✓ **Build Only:** Inclination increases, azimuth remains constant.
- ✓ **Build and Turn:** Both azimuth and inclination increase.
- ✓ **Drop and Turn:** Azimuth changes while inclination decreases.
- ✓ **Straight Path:** Both azimuth and inclination remain constant.

Also note that the Inclination and Azimuth from the reference point to the selected KOP will be zero while MD and TVD will be equal.

These MIA values were then input into a MATLAB algorithm to produce a wellbore trajectory to all five pay zones. To ensure a realistic trajectory, the shortest path was simulated when transitioning between azimuth directions. The shortest azimuthal path principle involves selecting the most direct angular route between two azimuths on a 360° compass. Instead of traversing the full circle, the difference between the target azimuth and the current azimuth was normalized to lie within −180° to +180°, ensuring the shortest rotational path.

Next, the generated well path parameters were input into a MATLAB algorithm employing the Minimum Curvature Method (MCM**)** to calculate the corresponding Northing, Easting, and True Vertical Depth (NET) coordinates.

From the resulting NET dataset, the coordinates corresponding to the randomly generated MIA values were identified and set as the locations of the five target zones. The derived NET dataset was then plotted to provide a 3D view of the complete well path. Additionally, the Northing vs. Easting curve was produced to analyze the azimuthal trajectory.

Points	M	I	A
Surface	0	0	0
KOP	1100	0	0
T1	2100	35	170
T2	3500	80	340
T3	5600	80	97
T4	7200	55	97
T5	9200	90	220

Table 1: Randomly Generated MIA Values for Well Trajectory

Results

Figure 2 below shows the top view of the complete well path, as depicted in Figure 1 below. It can be observed from Figure 2 that when the well path shifts to a new location, and the azimuth of this new location is taken as the reference direction, that means shifting the reference axis in the direction of the current azimuth, this shift causes the well path to display distinct patterns. Following this principle, it can be observed from Figure 2, that the well path either moves left, right, or follows a straight trajectory. Notably, the wellbore's direction is no longer referenced from the previous azimuth but rather from the newly established azimuth.

From this new reference direction, the position of the next target azimuth can be determined by applying the principle of the shortest azimuthal path. The wellbore will always take the shortest route, either clockwise or counterclockwise, to reach the target azimuth. In cases where the azimuth remains constant (i.e., the well path follows a straight line), the trajectory will directly proceed to the next target.

Another key observation from the wellbore path does not hit the target directly at the new azimuth but rather approaches from the other side of that angle. For example, If the new azimuth is 120°, the path can be noted to approach the target at an angle equal to **mod ($\mathrm{Azi}_{\mathrm{current}}$+180, 360)**. This relationship highlights a mirrored behavior when the wellbore approaches its target, reinforcing the idea of symmetry in the azimuthal path.

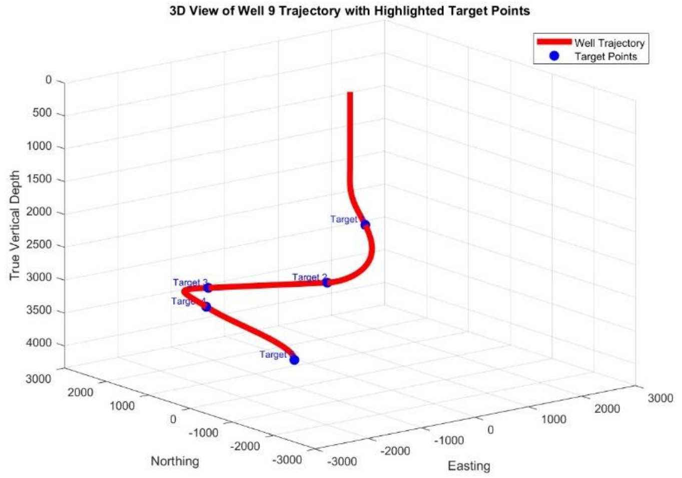

Figure 1: 3D View of generated well path

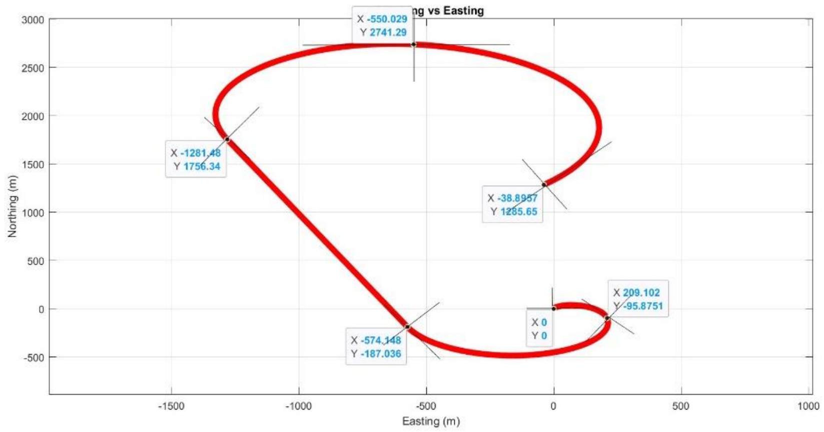

Figure 2: Top View of generated well path

Conclusion

These observations are important because they provide valuable insights into how wellbore trajectories can be accurately predicted and optimized. By recognizing the pattern of azimuthal shifts and ensuring that the shortest azimuthal path is always followed, the well path can be controlled more effectively, reducing unnecessary deviation and minimizing the time and energy required to reach the target. Moreover, understanding the mirrored behavior when approaching the target allows for better alignment of the wellbore with the target zone, optimizing drilling efficiency and accuracy.

The ability to predict and model the path of the wellbore based on these principles enhances the ability to design and execute well trajectories with greater precision, contributing to more successful and cost-effective drilling operations.

References

1. Zaremba, W.A.: “Directional Survey by the Circular Arc Method, SPEJ February 1973; Trans., AIME, 255.
2. Mason, C.M., Taylor, H.L.: “Systematic Approach to Well Surveying Calculations”, SPE3362, June 1971
3. Sawaryn, S.J. *et al.*: "Safety Critical Systems Principles Applied to Drilling Engineering and Well Services Software", SPE84152 presented at the Annual Technical Conference and Exhibition, Denver, Colorado, 5-8 October 2003.
4. Xiushan, L., Jun, G., "Description and Calculation of the Well Path with Spatial Arc Model," Natural Gas Industry, Beijing, Vol. 20, No. 5, 2000, 44-47.
5. Wilson, G.J.: "An Improved Method for Computing Directional Surveys," J. Pet. Tech., Vol. 20, Aug. 1968, 871-76.