The Second Edition of European NO DIG Conference

Segrate (Milan), Italy
25TH May 2023

Paper 10

HDD Industry and Gyroscopic Navigation Intersects

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ABSTRACT: HDD drilling projects are getting longer and longer, creating a continuous demand for innovative solutions. Several years ago, the intersect process was invented to double the length of the HDD crossings. Since then, intersect projects have become a common practice in the HDD industry. Today, we see intersects planned for other beneficial reasons that can include relatively short crossings. Some of these more relevant advantages include managing risks of inadvertent fluid releases to the surface during the drilling process and casing installation on either side of a planned crossing to engineer hole stability through granular formations to bedrock.

Several guidance systems are available for these intersects; however, it's not only the "intersect" that is important but also the integrity of the entire bore path. With highly accurate navigation, deviations tend to reduce significantly, allowing for stated radius specifications to be adhered to throughout the entirety of the pilot bore. All steering systems will have tolerances, and often some corrections will be required to complete an intersect. Accurate steering will reduce the required intersect corrections (S-Curve) substantially, where added deviations will lengthen the distance to complete the desired bore path within specifications. Intersects with a Gyroscopic steering tool will allow for more efficient intersects, and reduce the required time for the intersects, due to the high degree of accuracy.

1. INTRODUCTION

All steering systems will have tolerances, and often some corrections will be required to complete an intersect. Accurate steering will reduce the required intersect correction (S-Curve) substantially, where additional deviations will lengthen the distance to successfully complete an intersect within specifications. This paper will discuss the complications posed by long HDD bores, the challenges with accurately steering an intersect HDD bore, and will discuss an intersect HDD case study. In this paper a typical (S-Curve) calculation will be made to show the implication of small deviations, caused by steering system tolerances. A simplified mud pressure graph with calculated high-pressure zones (Overburden) for a general crossing will be explained where the depth/length graph will show the intersect necessity.

2.1 CHALLENGES OF LONG HDD BORES

The HDD technology companies are always looking for innovations to push the limits of the trenchless industry. After several years of extending drill lengths to over 3000m from one side, the industry was looking for options to make longer crossings possible and reduce some of the risks in doing so. This push in the industry had several challenges and required advancements in guidance technology.
Drill pipe dimensions over the years have increased substantially from 2-7/8" (OD) at the start of the HDD industry about 40 years ago, to 6-5/8" (OD). Even 7-5/8" (OD) drill pipe and bigger is not uncommon in Europe anymore. Larger drill strings have increased tensile strength, however complications still existed to steer accurately over long

distances. With very long HDD crossings it is not uncommon to have a large amount of stored residual torque within the drill string when steering and rotating the drill head.

On long crossing projects, drill pipe torque became quite high during drilling operations. This would occur even in perfect conditions while executing textbook drilling practices. Accurately steering a smooth and straight pilot hole reduces the related downhole torque over the length of a bore path over distance.

Often, a rig can experience a couple of rotations on surface before monitoring any rotational movement at the Bottom Hole Assembly (BHA). This can make steering in a desired direction extremely challenging. For example: If you would like to steer directionally (Right / 9 O'clock) it may be difficult to achieve this accurately with stored energy in the drill stem.

2.2 GYRO STEERING SYSTEM ADDRESSES INTERSECT CHALLENGES

Vector Magnetics was the first company who developed a system where the distance between the two drill bits could be measured. This made intersect operation increasingly more successful without the need for surface tracking at the planned point of intersect.

Most of the intersect crossings today are very long and will cross areas where surface access is difficult or not possible. In the past, intersect projects were completed by planning the intersect zone in a section of the bore where surface tracking via wire coils could be done on both holes simultaneously, allowing the connection between holes to be achieved. This was difficult due to the limited accuracy of surface tracking specifically at greater depths.

Although intersects were completed using this method, often the bend radius at the point of intersection was not within specification tolerances as the two holes were not in great alignment at point of intersect. Once an intersect had been made, if out of radial tolerance, corrections to fix the radii could be time consuming and at times not achievable. To solve this, solutions would then be pushed into the reaming stages of the operations. This involved increasing the final ream sizes through the point of intersect to counter the radii error incurred at the point of intersection.

The ultimate solution is to have a steering system that is not reliant on surface tracking for accurate positional verification. Greater accuracy not only allows for a smoother, radially compliant drill path but also reduces the positional error at the planned intersect zone. With smaller corrections to be made in the intersect zone along with a more advanced steering system, a point of intersect can be achieved within the tolerance of the specified radii.

With the gyro steering systems, not only can this accuracy be achieved, but it does so without having any influences from external magnetic interferences. This allows for combined radii to be calculated throughout the entire drill path with confidence, assuring compliance with the tolerance of the specification. A smoother drill path well within engineered specifications translates to lower friction on the product line during install reducing anticipated pull forces substantially.

During the drilling operations from both sites, many HDD contractors have developed procedures to reduce the risk for damaging bits and other down hole tooling. While sufficient distance is kept between Bits, Annular Pressure is monitored by the dormant side to view any increases in annular pressure. These pressure fluctuations can be good indicators of fluid communication between holes. If the intersect is completed at the first attempt, the BHA is pushed forward into the opposing hole and the point of intersect is measured for radii. Once the intersect point is completed, separation between drill bits is maintained through clear communication as one BHA follows the other to daylight. Measurements are continued as the BHA from one side is advanced into the other hole. This creates an As-Build with completed measurements from one side entry location to the other.

If no direct intersect is made, drilling is continued from one side while the other maintains enough distance (Bit to Bit measurement) to avoid any collisions down hole. Drilling is continued to a point where both steering systems can be aligned. At this time, a Radar system is activated measuring an exact deviation between holes. The information is used to calculate and plan the intersect curve based on separation and radii specifications. As every project has different challenges, an intersect point may be delayed to a different location in order to ensure each hole can be aligned appropriately and keep the intersect point within radial specifications. Drilling continues using real time Pitch and Azimuth from the Drill head assuring alignment can be kept with logged information captured from the opposite hole.

Today, downhole ranging systems are all Magnetic in nature and measure the distance between a transmitter and a receiver in the drill bits based on electric power. During an intersect, due to the relatively short distances between the drill lines, the typical tolerance of 2% for magnetic measuring is acceptable. The potential interference risk is also reduced as the measurements are very local around both drill bit locations and typically deep underground isolating the two steering systems from other potential interferences located further away. The initial steering accuracy is essential to making a good intersect. This reduces the potential of outlying interferences to become relevant when ranging from one tool to the next. When approaching the planned intersect zone, the greater the distance between tools, the greater the chances of external influences playing a role on the measurement process. (Ranging from one hole to the next)

Figure 1 shows where two drill lines are measured with a separation of 1m. The radius is specified as 1000 meters. A plan is calculated to accomplish a smooth radially compliant intersect. In the example, the calculated drill distance required (L) to complete the intersect is 54m if the allowable radius for the pipeline is followed. Other calculated designs to close this distance could be preferred, based on feasibility of adhering to the plan to do so. Of course, any failure to stay on the planned alignment would only lengthen the required distance to bridge the gaps between holes. Alternatively, any radical adjustments made may compromise both holes at the intersect point radially,

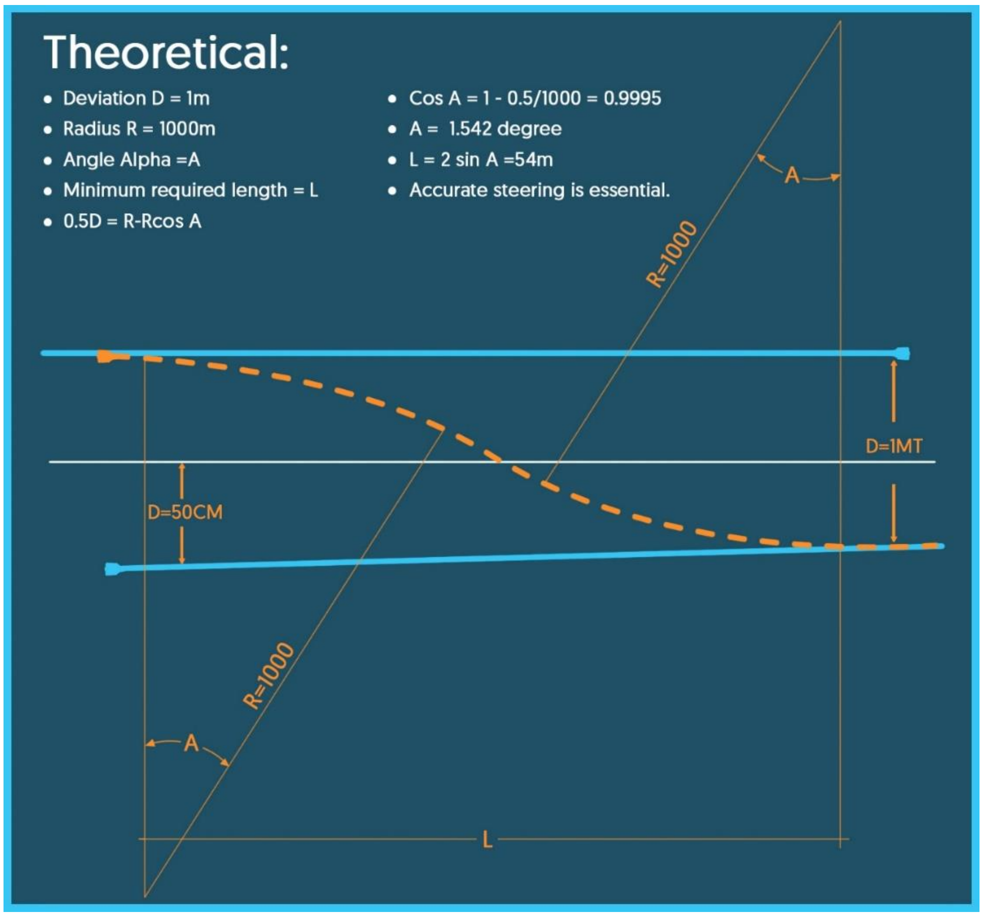

Figure 1. Example Calculation for Determining Intersect Radii.

2.3 CASE STUDY: GYRO STEERING INTERSECTS

An intersect project with a length of over 4500m is shown in Figure 2, where the depth at the planned intersect zone was 90m. For a project of this length, there are many challenges to overcome for successful completion. Any guidance uncertainties will only further compound these challenges. For projects such as these, extreme accuracy and minimal deviation is paramount.

This complex project was constructed using the Drillguide Gyro Steering Tool and was drilled with only 80cm of differential at the planned intersect point. Once a plan was designed to close the distance within engineered specifications, a successful intersect was achieved within a few hours.

Figure 2. Location of an Intersect Drill with guidance from a Drillguide Gyro Steering Tool

With a crossing of this length, several operational issues needed to be addressed. Risks of inadvertent fluid release on either side of the operations could become environmentally detrimental to the successful installation. Afterall, even half the length of the drill (2200m) from a single side is a long distance for one drill operation. Although planning this project as an intersect reduced such potential substantially, the risks of a “Frac-Out” or “Blow Out” were still very real. This validates the need for anticipated drilling pressures to be calculated and followed using annular pressure monitoring and logging during drilling operations.

2.4 MANAGING DRILLING FLUID PRESSURE WITH INTERSECTS

An additional challenge that was often encountered while completing longer crossings, was higher annular mud pressure. The higher pressures often resulted in a loss of circulation back to the drill rig or even inadvertent fluid releases to surface. This event is commonly referred to as “Frac-Outs” or “Blow Outs”. The required mud pressure to transport the cuttings from BHA to entry point is related to many variables including hole length, hole size, formation, pump rate, mud products/additives, and cleaning/reclaiming abilities of the drilling fluid to remove solids.

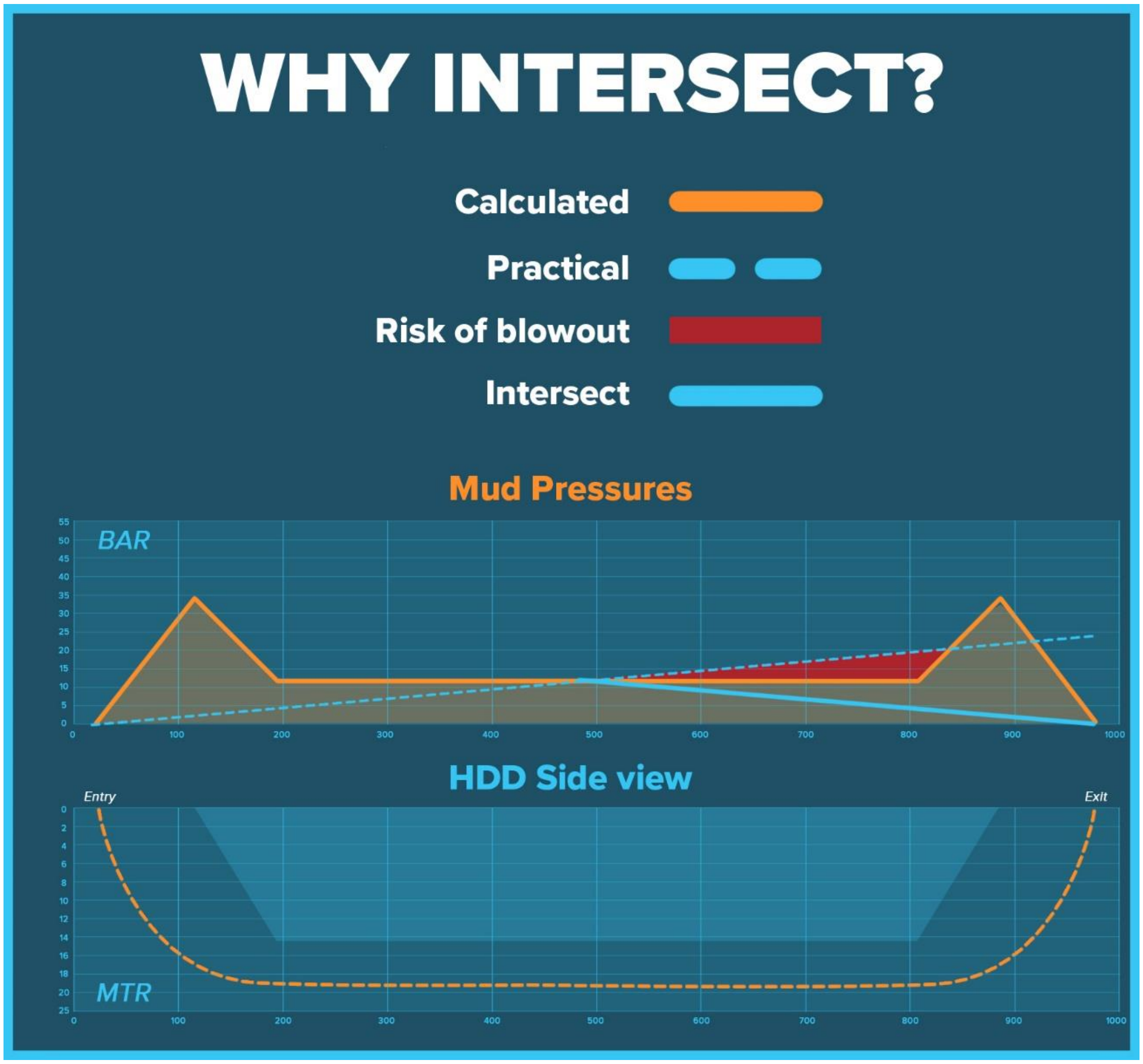

Figure 3. Theoretical Mud Pressure Diagram

In Figure 3 you can see a simplified theoretical mud pressure diagram. By applying theoretical annular pressure calculations, risks of inadvertent fluid releases can be anticipated. The illustration shows the case of a crossing executed from one side of the river (Blue dotted line) as compared to the reduced risk of introducing intersect operations to the same project (Orange line). The Red area indicates the drilling pressures exceeding the calculated limiting overburden pressure (Increased risk of inadvertent fluid release). As such, today we see more projects planned as intersects even when length is not the underlying obstacle to overcome.

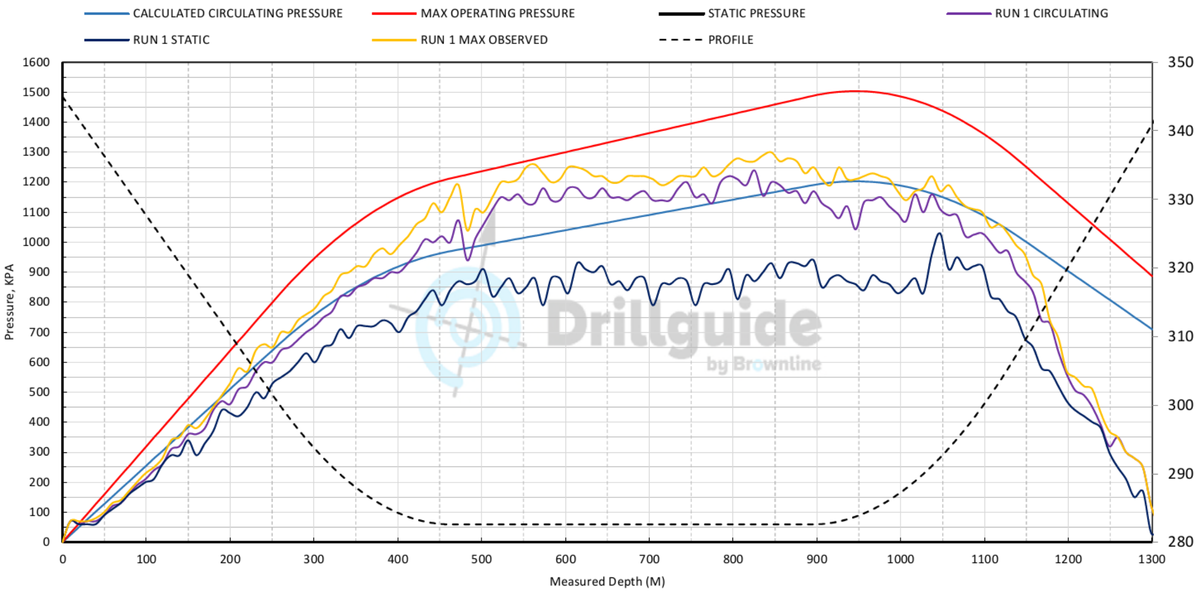

Figure 4. Annular Pressure vs. Calculated Pressure

In Figure 4, an example of monitored Annular Pressures vs. Calculated Pressures based on: (Depth of Cover, Formations/Soil investigations, Pump Rate, and Drilling Fluid Properties) is shown. Pressures are monitored in real time at the BHA and compared to allowable parameters. The need to trip out to clean the hole and reduce annular pressures is determined based on the ability to keep the actual pressures within calculated tolerances. Annular pressure monitoring has become standard work practice and has reduced the frequency of inadvertent fluid releases substantially throughout the years.

3. CONCLUSION

The HDD industry is constantly developing but with more investigation and knowledge we can push the boundaries much further. We have seen steps forward with, for instance, the Intersects, where new possibilities occurred, but at the same time additional risks developed, especially when the knowledge and experience is missing. HDD is becoming a more professional industry and therefore we need more knowledge and investigation.