Directional Drilling is a Science: The more we know, the more we have left to learn
Preface

There is no doubt that the drilling industry has been through tremendous changes over the past few years. Major directional drilling companies are using sophisticated technologies to reduce costs while providing better quality for their clients in the challenging market of the present. However, in order for smaller companies to be successful in this environment, it is necessary for them to adopt new and expensive technologies in order to better meet the needs of their clients.

The key to success is through enhancing drilling efficiency, by reducing NPT at the same time. Drilling efficiency is a term frequently used in the drilling industry; however its value is frequently underestimated. Drilling efficiency requires a higher degree of accuracy in the placement of boreholes, while improving overall rates of penetration. In addition, a high level of drilling efficiency will reduce the total cost of drilling while providing improved directional control, drill further, eliminate sliding, provide better hole cleaning and smoother boreholes, present fewer chances of sticking, improve logging tool responses, and ease the running of casing. Rotary Steerable Systems (RSS) were introduced to the oil and gas industry in the early 1990’s in order to respond to requirements that are more complex every year. These systems have the ability to drill faster, farther, and more accurately than conventional steerable systems, fulfilling a high level of drilling efficiency.

This paper will present an overview of Rotary Steerable Systems, the benefits and best practices with RSS, and discuss well planning.
Overview

Rotary Steerable Systems consist of two basic types; “push-the-bit” and “point-the-bit”. Pushing the bit refers to exerting lateral side force on the bit as it drills ahead. Point-the-bit systems operate by placing a bend in the system much like a standard motor assembly. This bend is held geostationary with respect to the formation.

To understand the point-the-bit principle, one can make comparisons to conventional drilling systems that use motors or turbines. A bent housing and stabilizer on the bearing section allow the motor to drill in either an oriented (sliding) or a rotary mode. In the rotary mode, both the bit and the drill-string rotate. The rotation of the drill string negates the effect of the bent housing, and the bit drills an over-gauge straight path parallel to the axis of the drill string above the bent housing. In the sliding mode, only the bit rotates. The motor changes the well course in the direction of the bent housing, and the drill string slides down the hole behind the bit. In the point-the-bit system, the ‘bent housing’ is contained within the collar of the tool. This ‘bent housing’ is controlled by means of an electric motor which rotates counter to the direction and at the same velocity as the drill string. This control allows the ‘bent housing’ to remain geo-stationary (non-rotating) while the collar is rotating.

The Rotary Steering System introduces many advantages over conventional steering systems which include:

- Eliminating time spent aligning the toolfaces; the rotary steerable tool controls it automatically.
- Hole cleaning is improved as the pipe is rotated both while steering the well and drilling straight. ECD will be kept consistent, rather than fluctuating as the hole is loaded with cuttings while sliding and then cuttings beds agitated and unloaded while rotating.
- Drag, which can cause shocks, vibration, and stick-slip is reduced compared to sliding. This results in a more consistent weight-on-bit and reduced stress on drilling equipment.
- There is less chance of the drillstring becoming stuck because of continual movement.
- Hole quality using the extended gauge bits matched to the RRS is much improved, with lower micro tortuosity, lower friction factors, easier casing runs and large maximum collar pass through diameter.
- Deviation rates are more consistent as there is no change in mode between steering and not steering to produce the required rate.
- Hire string rpm can be used, as there is no bend in the mud motor to limit rpm.
- Wellbore profiles are generally smoother, with no transition ledges resulting from changes between rotating and sliding modes
- Increased and improved quality of LWD data due to continuous rotation.
- Higher ROP due to absence of need to slide
- Longer reach with lower drag due to rotation
Best practices

The best practices for the rotary steering system include tripping in, drilling plugs, drilling the shoe, and rathole to gauge hole transition.

Tripping in

Tripping in should carried out with RIH filling the drill pipe as per normal API standards and/or customer requirements to 30m above the planned TOC (Top of Cement). Before establishing circulation, it is necessary to break in RSS rotary seals to ensure the lubrication. After the seals have been broken in, mud circulation should be slowly established to prevent hydraulic shock and gradually increase flow rate to optimum circulation rate.

The tool must be set in the “Zero” deflection position. The rotary torque should be recorded because this is likely to be the cleanest the casing will be regarding cutting accumulation and off bottom torque. A wash down should be carried out once the full circulating parameters have been established.

Close time monitoring of the RSS deflection should be carried out while drilling cement, casing shoes and landing collars, and supervision of drilling operations must focus on avoiding the chance of tool deflection being set manually.

If the tool does take a deflection setting, the string should be immediately removed off bottom and the tool must be reset to zero deflection with confirmation in shaft.

Drilling Plugs

Parameters must be established and the last stand down must be washed at full flow or as close to near full flow as possible. Tag cement and plugs afterwards, and drill the cement away until reaching the plugs. Confirm location by checking for sudden reductions in ROP and smooth torque.
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When having problems drilling plugs with a conventional rock bit and rotary BHA, one option often cited is to reduce flow rate to “heat up” and to spud the bit to break up the plugs. However, reduced flow rate is not an option with a PDC bit. It is essential that a PDC is kept cool, and spudding is not an acceptable practice. It is essential to utilize high flow rate, low bit weight, low string RPM and patience.

It is easy to spin the plugs with a PDC bit since it is a drag bit that cuts in shear. Even “non-rotating” plugs can spin especially the top plug. Some spinning is unavoidable, even desirable since the heat build-up from friction can help to weaken the rubber but avoid long periods on bottom with low steady torque. It is usually the first light contact with the rubber that cuts the most effectively. This is often seen as an increase in torque when tagging the plug. It is this feature that should be exploited. Pick up frequently and return to tag bottom gently. Note any increase in torque and take this as an indication of how the bit is engaging the plugs.

Due to their parabolic profile, some PDC bits will core out the centre of a plug, leaving the wiper rings intact. This in combination with a small junk slot area can cause the bit to “piston” off bottom. The wiper ring forms a seal round the bit and the effect is the same as packing off. String weight decreases while bit weight and pump pressure increase. This can occur repeatedly as each wiper ring is detached. The natural reaction is to cut back the strokes and pick up off bottom to try to clear the bit. In most cases it is more effective to stay on bottom and let the increased pressure blow the ring past the bit. Watching the weight indicator and pressure gauge swing up and down can be alarming but it is necessary to persist as long as nothing else is at risk.

It is important to watch for packing off. All pressure increases are to be treated as suspect and action must be taken to minimize potential damage. Momentary pressure spikes do occur, but they are tolerable as long as they clear quickly. The most likely pack off when using long gauge bits is around the bit, but if a sustained pack-off occurs with tool seals, it is important to consider taking a cautious approach.
**Drilling the Shoe**

The interface between the plugs and the float is a critical area, and extremely important in establishing drilling efficiency. The bit is relatively safe when sitting on rubber, but the float is a composite of hard cement, plastic and aluminium with a hole in the middle. The profile of the bit does not match the top of the float, and so must be drilled into the cement carefully until all the cutters are in contact with the float. It is possible for the center of the bit to be unsupported even at this point if there is mud below the plugs, but procedure is the same as drilling a new bit into hard formation.

Initially, only a few cutters are in contact and the watercourses are not yet directing the flow properly. Excessive Weight-On-Bit (WOB) at this point will damage the cutters since contact with cement will cause higher friction, causing heat damages to PDC cutters. A similar scenario can occur if the plugs are landed on a separate landing ring. Then only the gauge cutters will be in contact till the ring is drilled out.

Case must be taken when breaking through the float. There may be an empty pocket with no cement directly below the float. The bit will drill out the center and will be supported only on the gauge cutters. WOB should be reduced during breakthrough to prevent overloading the gauge cutters. The same goes for drilling the shoe.

Newer aluminium reaming shoes drill easily enough, if a little slowly. Care must be taken to avoid “trepan” the shoe, especially with a flat profile PDC, which involves cutting out behind the nose leaving an uncut disc of aluminium to be pushed to bottom.

**Rat-hole to Gauge Hole Transition**

The rat-hole is a repository for debris and cuttings. The reduction in AV as fluid from the smaller section below enters the larger rat-hole means cuttings tend to ‘fall out’ on the low side in the rat-hole while drilling ahead. As each BHA component passes through the rat-hole on trips in and out of the hole it has the capability to disturb these cuttings and lift them in to the
flow stream. There is once again the potential for packing off in the reduced ID of the casing if the pumps are bought up too fast.

String RPM must be kept to a minimum while back-reaming or rotating off bottom in the rathole. High rotary speeds off bottom have a tendency to generate BHA Whirl and / or lateral shocks as the BHA is not in compression or braced against the borehole wall as is the situation while drilling.

Vigilance is important when Reference Stabilizer and other stabilizers in the BHA transition from the rat-hole to new in-gauge hole. This change in BHA / borehole geometry is a potential risk area regarding torque and pack- off situations. In the event that a Leak Off Test or Formation Integrity Test is required after drilling 3m of the new hole, then care should be taken when pulling back into the shoe and resuming drilling after running back to bottom.
Well planning

It is vitally important to establish responsibility among everyone at the site. Everyone must understand what is happening downhole at all times, not just the directional driller. With more information on hand and more planning done, the chances of success are even better. Many factors are involved in RSS well planning, but the most important ones are as follows:

**Depth in/ out (MD&TVD):** Accurate depths and lengths must be established for optimal tool deployment and tool setup. For example, the length of the section drilled is required to calculate how many tools are to be deployed. The TVD is used to calculate hydrostatic pressure, so that the correct set up of the tools DLS can be established. Everyone must know which sections are build, drop or turn, etc.

**Maximum dog leg to pass through:** Past operation data should be checked to determine at what point tool damage occurs due to overly high dog legs. It is required to have the most accurate information available on the formation. An investigation should be carried out on whether the quoted pass through dog leg is realistic, due to dog legs being frequently higher than planned.

**Bottom hole temperature:** It is important to check where the formation information has come from.

**Rotary table maximum RPM:** It is necessary to establish the maximum and minimum rotary table speeds that can be achieved without changing gear. This information is used to set up the telemetry system of the tool.

**Typical Slide - Rotation ratio:** Need to know the typical percentage of time which is spent sliding versus rotating. If little time is typically spent sliding and the objective of the run is to improve ROP, then it may be necessary to consider alternative wells.

**Hole size for run:** Preference should be for run in hole through a larger gauge of hole to avoid reaming to bottom.
Typical bit issues: The performance of the tool is very sensitive to changes in hole gauge. Everyone on site must be aware if holes are prone to being washed out or if the bits are pinched out. Moreover, everyone must know what types of bit are used to drill sections in offset wells to assist with bit recommendations.

Conclusion

While this technology has been around for over twenty years, it has acquired something of a negative reputation because this tool has an extremely small margin for error, sometimes equal to zero. Other systems have higher tolerances for deviation in dogleg severity in comparison to the RSS. This technology has higher acquisition costs in comparison to conventional steering systems, and inadequate pre-planning can result in higher losses than with conventional steering systems.

In order for the system to accomplish higher drilling efficiency and to reduce overall costs, it is absolutely necessary to have the most accurate information available and a very high level of competency and professionalism in the team. These are difficult requirements to meet, but drilling companies that cannot increase their drilling efficiency will eventually find that they have no clients, due to the competitiveness of the market. The question is not whether RSS is right for their operations; rather it is whether the company can operate at a high enough level to proficiently utilize the technology.
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References

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