Extreme Equipment Sales & Rentals
PowerDrive – Connection Fatigue
Revision 1.0

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Applicability: PowerDrive Orbit
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Background Information

Rotary steerable BHA's typically allow for more rotary connections to be subjected to more bending/rotating fatigue cycles. This increases the overall risk of operation of these connections. This is especially true in interbedded geology where large localized hole trajectory changes can create very high bending stresses on these connections (see Appendix for details).

In typical PowerDrive BHA's, the connections from the top of the PowerDrive control collar to the motor are at an elevated risk of high bending stresses and high speed rotation. There are some basic recommendations that can be followed to minimize the risk of fatigue failure of these connections.

Material Endurance Limit

Not all non-magnetic drill collar material is alike. Typical 'commodity' iron may not carry any endurance limit specification (the primary specification for fatigue resistance). Higher grades of drill collar material carry an 'endurance limit' or 'endurance strength' specification. This specifies the cycles to failure for a given loading condition and is typically verified in the material certification. Extreme recommends at least 80ksi at 100,000 cycles and/or 65ksi at 10,000,000 cycles.

Overall Material Properties

A balance of overall material properties and chemistry can minimize the risk of material yield, surface corrosion, and other conditions that put the material at risk to fatigue in operation.

Typical Property Requirement	
Yield Strength, 0.2% Offset	140 - 170 ksi
Ultimate Tensile Strength	Min 155 ksi
Elongation in 4D	Min 20%
Reduction in Area	Min 60%
Hardness	301 – 425 BHN
Charpy V-Notch, Energy, Min @ 250C, (770F) or lower	Min 100 - Average Ft-lbs
	Min 80 - Single Value - Ft-lbs
Fatigue Strength	± 65 ksi @ 10 Million Cycles
	± 80 ksi @ 100,000 Cycles

Surface Treatments

Compressive surface treatments of drill collar materials after machining connections increase resistance to fatigue. Cold roll and shot peen both give non-magnetic drill collar material a surface layer with compressive stresses that lower the stress levels during operation.

Fatigue Resistant Premium Connections

Several premium drill collar connections are being offered commercially on the market. These feature increased radii in thread roots and increased cold rolling pressure. These have been observed in lab testing to increase cycles to fatigue by up to 10X over standard API connections.

Reuse Limitations and Inspection Frequency

Proactively limiting the time between connection recuts reduces the risk of fatigue failure. Since fatigue is related to surface material, face-chase machine operations with minimal material removal can 'reset' the fatigue stress cycles to failure.

Connections are inspected when returned for service. Non-destructive methods are used in all typical inspection methods to identify fatigue cracks in the connection before propagation to failure. The more frequent these inspections, the more likely a connection crack can be identified before it fails catastrophically in operation.

Makeup Torque

Cumulative fatigue damage is directly related to static makeup stress in the connection. Minimizing the makeup torque to the lower limit of the recommended tolerance (given connection type, ID, OD, etc) can help minimize static stresses. This does sacrifice other mechanical aspects of the connection.

Bending Strength Ratios

Bending strength ratios as defined by API should be calculated and optimized for each actual connection geometry run in susceptible positions in the BHA. Wear and actual measured dimensions should be used to ensure that the stresses are balanced properly between the pin and box.

Stress Relief Grooves

API stress relief grooves are known to reduce the stress state in critical parts of the connection. These can increase fatigue life. However, because of the necessary recut length, these can significantly reduce the useful life of downhole components.

Note: Stress relief grooves increase risks for fatigue and other stresses in smaller connections (NC35, NC38, etc) on 475 collars.

Reaming Through Curve Sections

Any BHA components below the motor rotate at elevated speeds with flow. Reaming with motor-assisted rotary steerable assemblies in areas of high dogleg should be avoided if possible. If reaming is necessary, flow rate and surface rotation should be minimized to keep bending fatigue cycles on the connections to a minimum.

Lateral Vibration

Periods of lateral vibration can increase bending fatigue stress and the number of cycles in BHA connections. Lateral vibration in the string should be mitigated whenever possible.

APPENDIX: SHARP HOLE DISCONTINUITY WITH STRINGERS (FROM PD LOG INTERPRETATION GUIDE)

When drilling near formation dip angles in heterogeneous formation, significant changes in wellbore trajectory can be observed when encountering stringers, lenses, or formation properties which possess differential hardness. Geometrically, when encountering these stringers, there is some critical angle of incidence above which the PowerDrive will not be able to penetrate the stringer. This critical angle depends on the difference in hardness of the two varying rock types, geometry of the bit and BHA, and the WOB applied. If the bit and PowerDrive encounter this stringer at an angle less than the critical angle, it will “ride the dip” and the bit will continue to scrape along in the softer rock, unable to penetrate the harder rock. If the angle of incidence is greater than the critical angle, the bit will begin to penetrate the harder rock, but will slip along the interface, causing an instantaneous change in angle due to differential forces acting on the bit. The geometric constraints of the hole, bit and PowerDrive geometry will drive the maximum deviation that can be achieved at this interface, as the bit gauge pads, pads on the PowerDrive, and control collar OD mechanical restrict this motion against the wellbore. This creates a visible hump in the continuous inclination as the PowerDrive and following BHA are bent around this discontinuity. Depending on the thickness of the stringer, the tool will either return to its target inclination once it is fully in the new rock, or it will immediately begin to exit the hard stringer into the softer base rock. When exiting, again the differential forces acting at the bit cutting two types of rock will cause rapid exit into the soft formation, causing another deviation of opposite direction and potentially greater magnitude as the hard rock creates a wedge or ramp into the harder formation. If the PowerDrive was able to correct the angle while in the harder layer, it will appear to “overshoot” as the bit is forced out of the hard rock and into the soft rock, again creating a discontinuity in hole angle at the interface. These angle discontinuities can create severe bending loads on BHA components, as they are subjected to what is essentially three-point-bending loading. The continuous directional measurements represent the shape of the BHA, not the actual dogleg of the hole at that point. In extreme cases where the borehole is especially large, the BHA small, and the bit gauge short, most frequently in 6.75” hole with 475 BHA components, the geometric freedom during these events can generate discontinuities capable of failing a rotary shouldered connection in a few hundred cycles, leading to rapid fatigue and eventual twistoff.

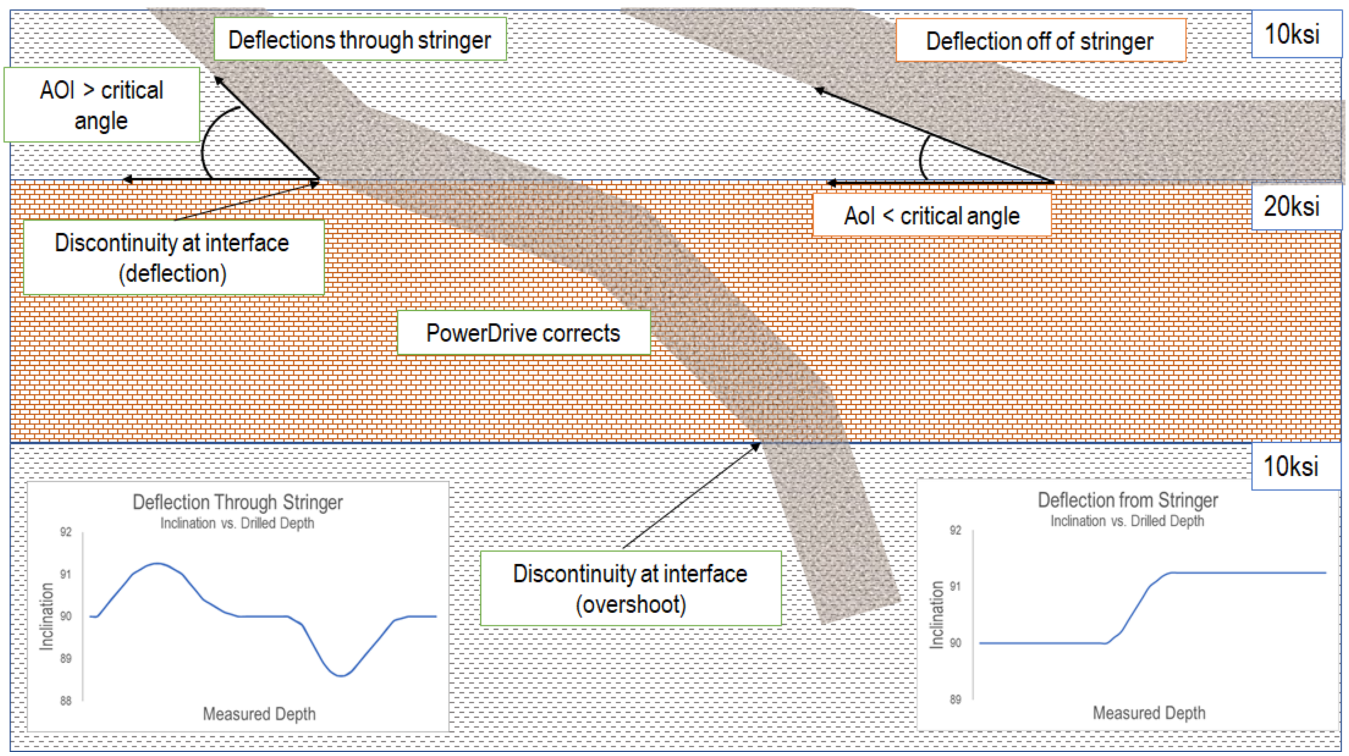
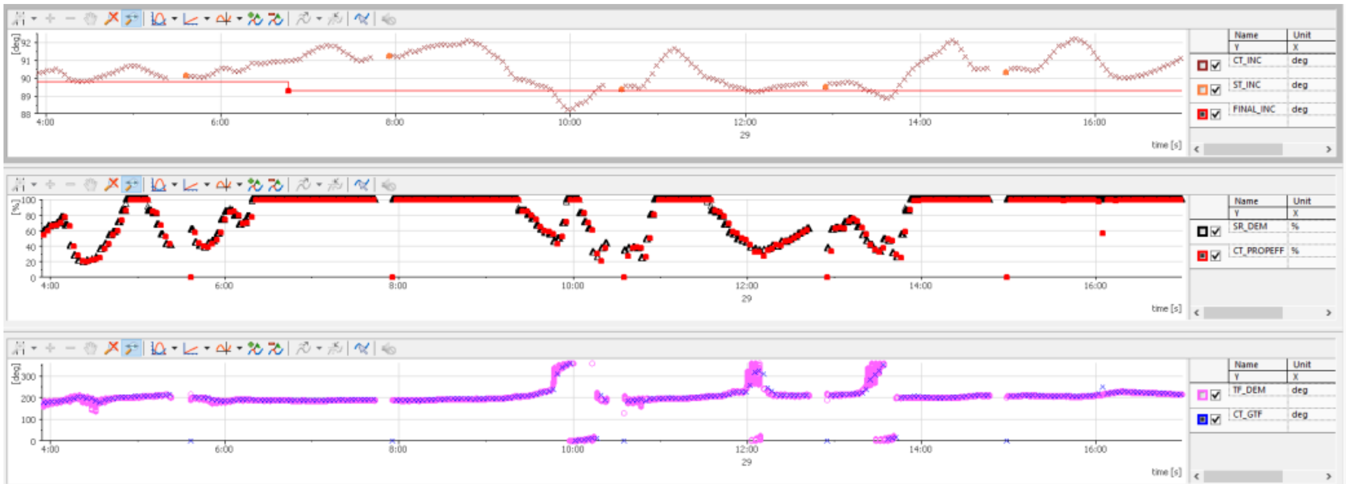
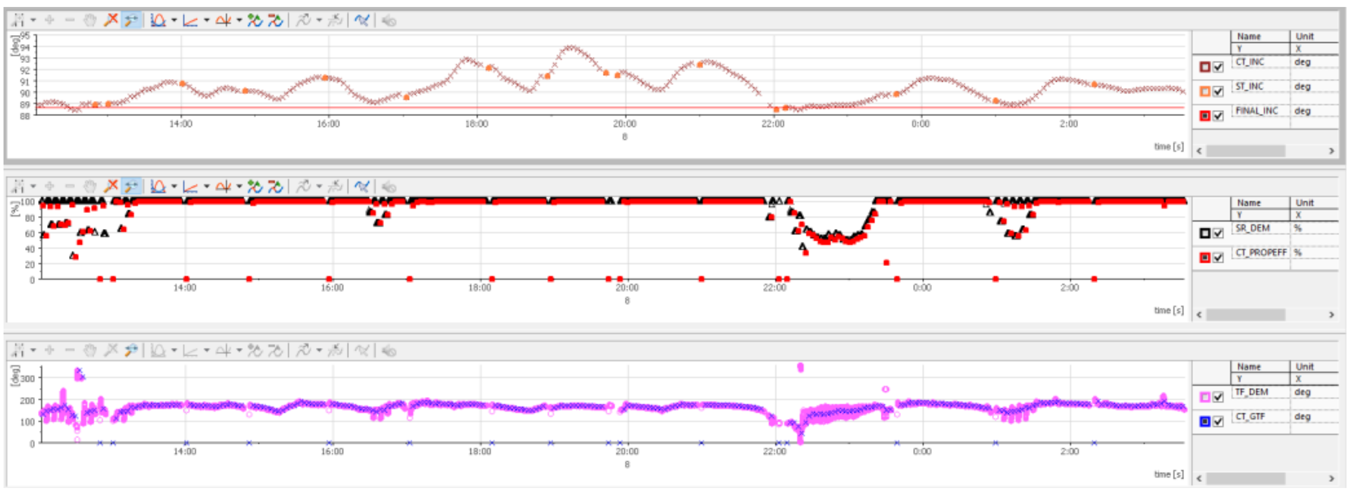


Illustration of idealized deflections through a thick stringer (angle of incidence greater than critical angle) and off of a stringer (angle of incidence less than critical angle) which generate angle discontinuities. The actual angles will depend on relative formation harnesses, geometry of the bit, bias unit, and BHA, and WOB and steering force applied.



Example of a PowerDrive encountering a stringer above the critical angle, being deviated upward, overcoming and returning to target, and overshooting target while exiting the stringer



Example of PowerDrive encountering stringer below critical angle – due to the non-planar nature of real rock layers and the varying intersection angles, there is some skipping effect, where the BHA "skips" off of the interface, and returns, unable to break through the interface even in 100% steering