



The Role of an Advanced Performance Roller Reamer in Today's Bottom Hole Assembly Applications.

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Abstract

A roller reamer has historically been included in many Bottom Hole Assemblies (BHAs), primarily to assist in wellbore gauge maintenance. Recently, however, the introduction of an advanced, sealed bearing roller reamer has made a wider range of applications possible, beyond the traditional role of this type of downhole tool.

An advanced performance roller reamer offers effective torque reduction and vibration suppression, combined with a state-of-the-art compensated sealed bearing and reaming structure that is designed for extended downhole life and reliability. The reamer design also incorporates a range of cutter configurations, including the use of synthetic diamond enhanced insert technology and the latest techniques in hardmetal application. Cutter configuration options are selected based on the key performance requirements of a BHA.

The adoption of a standard method for the assessment and evaluation of cutter performance was also found to be an important factor in the successful introduction of an advanced performance roller reamer.

This paper discusses the key requirements and the latest applications for an advanced performance roller reamer. Product development features, fundamental design criteria, laboratory test results, BHA computer simulation results and field test case studies are described and presented.

Introduction

Today's challenging drilling environments demand superior performance from all tools in the BHA.

Complex and extended reach well geometries require that drilling torque is minimized to improve drilling performance.

Vibration induced while drilling has long been recognized as a significant area of concern. Many of the drilling BHAs used today include sophisticated rotary steerable systems, concentric hole enlarging devices and state-of-the-art Formation Evaluation While Drilling (FEWD) products. The performance and reliability of such equipment can be greatly improved when destructive vibrations are minimized.

As wells are routinely drilled to greater depths, the equipment used in the BHA is expected to endure operating environments with higher pressure and

temperature. It is critical that "on-bottom" time is optimized in such applications and unnecessary, costly, trips are avoided.

The quality of the wellbore drilled continues to be a critical issue. The definition of wellbore quality includes several attributes such as:

- In gauge.
- Smooth and free from steps or ledges.
- Free from abrupt doglegs.
- Free of keyseats.

The development and successful introduction of an advanced performance roller reamer, focused on the provision of a reliable solution to such challenges. The key objectives in the development of the reamer included:

- A greater level of reliability, with an effective sealed bearing design that would last significantly longer than previously available roller reamers. The sealed bearing configuration should also exhibit durability and effective pressure compensation in HPHT drilling environments.
- A selection of application specific reaming structures to match the formation characteristics of the well bore. All reaming structures should also include a profile that would facilitate bi-directional reaming.
- The ability to minimize drilling torque. The bearing design utilized should also retain its torque reduction capabilities even in conditions where significant side loading is present.
- The ability to effectively suppress vibrations while drilling, with primary focus on both lateral and torsional vibrations. Operating in such an environment should not compromise performance or durability.

New Product Features

The development of an advanced performance roller reamer resulted in numerous new product features and improvements over prior designs. In this paper, the more notable new product features have been selected for discussion.

1. Sealed Bearing Developments

The durability of the roller reamer relies heavily on the integrity of the sealed bearing. It should also be emphasized that the number of revolutions of the sealed bearing elements in the roller reamer will generally be over three times the number of drill string revolutions for a given interval. The identification of the mechanical forces acting on the sealed bearing elements during operation is also important. Simulation computer modeling of BHAs was carried out to assist in the development process.

A proprietary elastomer compound was selected for the bearing seals. In laboratory testing, this elastomer was found to be compatible with high speed applications, provide greater wear resistance, higher tensile strength, higher temperature rating and compatibility with all widely used drilling fluids. **Figure 1** illustrates the relative improvements in elastomer wear resistance, tensile strength and temperature rating.

An innovative dual seal configuration was also developed, including both radial and face seals.

The sealed bearing configuration also included a fully active compensator arrangement. A new, proprietary elastomer was selected for the compensator arrangement providing greater tear strength and temperature resilience.

The use of a new lubricant was included in the development of the sealed bearing element. The lubricant selected exhibited an ultra high viscosity, excellent load carrying capacity and extreme pressure properties. The lubricant was also found to be stable at higher temperatures. An enlarged lubricant chamber was incorporated in the primary shaft of each sealed bearing element and a series of migration ports were added to facilitate lubricant distribution. **Figure 2** provides comparative laboratory test results for the lubricant used in the sealed bearing element.

2. Reaming Structure Developments and Options

Application specific reaming structures were developed to address today's roller reamer performance requirements.

All reaming structures were extended to provide greater surface contact, increasing effective full gauge reaming life.

Laboratory analysis of alternative reaming inserts resulted in the inclusion of a new tungsten carbide (WC) insert grade and the introduction of an optional Synthetic Diamond Enhanced Insert (SDEI). The SDEI structure option is considered to be the ideal selection for highly abrasive applications or when extended run duration is anticipated. Laboratory testing of the SDEI resulted in significant improvements in both abrasion and impact resistance. **Figure 3** provides laboratory test results for both abrasion and impact resistance, SDEI vs. WC.

For applications where torque reduction or vibration suppression was determined to be the primary concern, and less demanding reaming requirements was

anticipated, a smoother surface, fluted reaming structure was included as an option.

All retention blocks used in an advanced performance sealed bearing roller reamer now include an innovative bi-directional reaming ridge. The ridged profile is created using the latest techniques in laser hardmetal application technology. The inclusion of this reaming ridge on both upper and lower retention blocks provides additional reaming capability in both directions to further extend operational life.

3. Other Developments

The reamer body geometry was designed to offer greater annular clearance.

The cutter retention mechanism now provides primary, secondary and tertiary securing features to provide unparalleled performance reliability.

A new method was developed to safely and reliably remove and install cutter assemblies.

Validation Testing

To validate the performance of the product, a series of "hostile environment" field tests were successfully concluded. The key test criteria included:

- HP/HT environment.
- Extended run intervals and "on-bottom" time.
- Highly abrasive formations.
- Complex well geometries with high mechanical forces acting on the reamer.
- Runs with frequent shock and vibration.
- Varied BHA configurations including PDMs, rotary steerable systems and concentric hole enlarging devices.

A set of standard measurements were established to provide a consistent method of dull cutter evaluation. The standard measurements included seal and bearing condition, gauge diameter and insert condition evaluation. Such types of measurement are widely accepted and used for drill bits, but to date, have not been routinely used in the evaluation of Roller Reamer performance. **Figure 4** provides details on the format and measurements used to assess used Reamer cutter assemblies.

A spreadsheet, shown in **Figure 5** provides a summary of the validation testing runs and the subsequent used cutter evaluation results for reference purposes.

Significant performance improvements were noted across the board in terms of seal / bearing longevity and reaming structure durability across the wide range of applications noted.

Computer Simulation Methodology

BHAs utilized in the validation testing program were also modeled to assist in roller reamer placement and to determine the mechanical forces acting on the roller

reamer. In each case, the modeling results were used to ensure that:

- The positioning of the roller reamer in the BHA did not adversely affect the desired path of the wellbore being drilled.
- The position selected for the roller reamer was the optimum position to support the BHA in the wellbore and assist in the suppression of potentially damaging vibration.
- Side forces and bending stresses at the roller reamer were within acceptable guidelines to maximize operational life.

Examples of simulation outputs are illustrated in **Figures 6 and 7**. These outputs compare BHA trajectory and show the mechanical forces acting on the BHA. This particular example is discussed in more detail in Case History Example 2.

Case Histories

Three case histories have been selected for further discussion. Each case history highlights varied BHA types and objectives.

- Case History 1 discusses a deep HPHT application.
- Case History 2 is an example of a complex geometry well bore drilled with a Rotary Steerable System.
- Case History 3 is a simultaneous drilling and hole enlargement application.

A summary of each case history is also included in the validation testing spreadsheet, **Figure 5**.

Case History 1

Two advanced performance Roller Reamers were included in an 8 ½ inch hole size performance drilling BHA. The Roller Reamers were included primarily to reduce torque and provide BHA stabilization. The anticipated Total Vertical Depth (TVD) of this hole section was approximately 21,000 ft. At this depth, the bottom hole circulating temperature (BHCT) was expected to be 350 to 375 degrees F. A BHCT in this range was considered to have a significant potential impact on the operational life of the sealed bearing assembly. Earlier data with conventional roller reamers indicated that a BHCT in this range could result in premature seal failure.

This hole section was successfully drilled using advanced performance roller reamers. The same reamers were used for three consecutive BHAs, accumulating a total of 283 drilling hours, equating to over 4.7 million cutter assembly revolutions.

The sealed bearings and cutting structure were evaluated after this run and were found to be in excellent condition. Dull grading was reported as E-E-E-IN-0.

Information provided from the rig site confirms that a

significant torque reduction, in the range of 35 to 40 percent was obtained.

Case History 2

An advanced performance Reamer was included in a rotary steerable BHA used to drill the 8 ½ inch hole section of a complex geometry well. In this case, the objective of the BHA was to build angle from 66 to 77 degrees inclination, turn azimuth from 14 to 30 degrees, hold tangent inclination, and finally, drop inclination to 45 degrees to intersect the desired target.

The reamer was included in this case to ream an abrasive, interbedded sandstone, minimize torque and suppress vibration. Offset data confirmed concerns with abrasive wear and vibration due to slip-stick. Additional offset data analysis on the performance of conventional sealed bearing roller reamers in this application indicates seal and bearing failure after 900,000 to 2.1 million cutter revolutions.

A mechanical analysis of this planned BHA confirmed that significant side loads and bending stresses were expected to occur at the Reamer for the duration of run. The results of the mechanical analysis are referred to in **Figures 6 and 7**.

This BHA was subsequently used to drill the interval from 9,775 to 12,600 ft. (TD) in a single run. All directional objectives were met with this BHA.

The wellbore gauge was maintained. Occasional tight spots were reamed prior to making connections.

Slip-stick was recorded during the run, but no significant shocks were noted.

The accumulated revolutions on the cutter assembly of this reamer were 2.6 million. This represents an improvement of 24 percent over the comparative offset data.

After completion of this run, the reamer's condition was evaluated. A dull grading was carried out on the cutter assemblies and noted as E-E-F-2-2.

Case History 3

In this example, a revised casing program in a deep HPHT well resulted in the requirement for an extended hole enlarging section, with the wellbore to be enlarged to 14 inches diameter with a concentric hole enlarging device simultaneously while drilling a 12 ¼ inch pilot hole. The depth interval to be enlarged was from 15,610 to 17,240 ft.

Two advanced performance reamers were included in this BHA, the first being above the LWD system and the second placed higher in the BHA, approximately 45 ft. above the concentric hole enlarging device. The reamers were included to minimize torque and vibration during the simultaneous drilling and hole enlarging operation.

As in previous cases, the BHA configuration was analyzed to assess the magnitude of the mechanical forces acting on it during the planned run.

This BHA successfully simultaneously drilled and

enlarged a 1,630 ft. interval in 271 hours. The BHA was pulled to lay down the rotary steerable system. Torque generation was maintained within acceptable levels of 12,000 to 15,000 ft-lbs. No significant shock or vibration was noted for the duration of this run.

An evaluation of the reamer cutters after this run noted that all seals and bearings remained effective. This was after an extended run, with over 5.7 million accumulated revolutions. The dull grading results were recorded as E-E-E-1-1.

Conclusions

The development of an advanced sealed bearing roller reamer has resulted in an effective solution for today's challenging drilling requirements. Application specific reaming structures, proven torque reduction and vibration suppression have broadened the uses of a roller reamer in the BHA.

Design improvements in sealing technology and bearing configuration have resulted in improvements in durability and reliability in deep HPHT and complex well profiles.

The introduction of SDEI reaming structures has resulted in extended reaming gauge life in harsh, abrasive environments.

Computer simulation modeling of the roller reamer(s) in the BHA has been shown to be a valuable tool in optimizing both reamer and overall BHA performance.

A standard method and criteria established to evaluate used reamer cutter condition resulted in consistent performance measurement. Future product improvements will also be facilitated by the use of this

information.

Acknowledgments

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Nomenclature

BHA = bottom hole assembly

FEWD = formation evaluation while drilling

HPHT = high pressure high temperature

WC = tungsten carbide

SDEI = synthetic diamond enhanced insert

PDM = positive displacement motor

TVD = true vertical depth (feet)

BHCT = bottom hole circulating temperature (deg. F)

TD = total depth (feet)

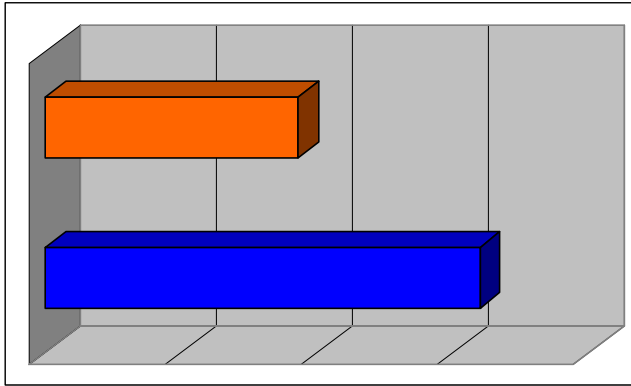
LWD = logging while drilling

References

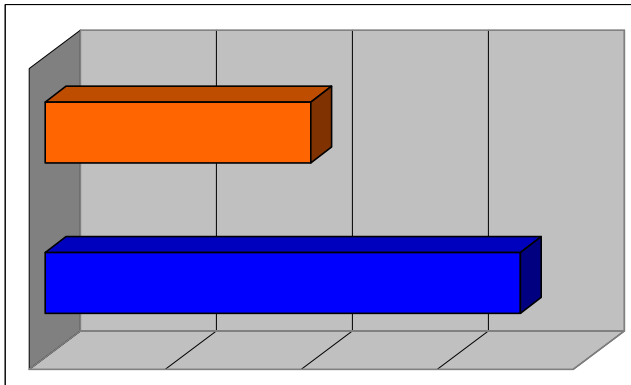
1. J.R.W. Crowe, W.G. Toohey and J.Holt, "A New Effective Method of Maintaining Hole Gauge using Synthetic Diamond Enhanced Inserts on Downhole Drilling Tools", SPE 57556, 1999 SPE/IADC Middle East Drilling Technology Conference, Abu Dhabi, U.A.E, November 8 – 10.
2. Williamson, J.S. and Lubinski, A., "Predicting Bottomhole Assembly Performance", *SPE Drilling Engineering* (March 1987).
3. Popov, S, "Sealed Journal Bearing Reamer Has New Applications And Meets Operator's Criteria", *Tech Trends, Hart's Petroleum Engineer International*, February 1997.

Figure 1 – Improvements in Seal Properties

Comparison – Wear Resistance



Comparison – Tensile Strength



Comparison – Temperature Rating

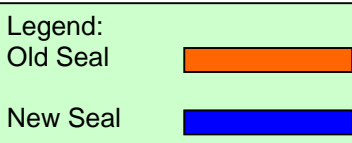
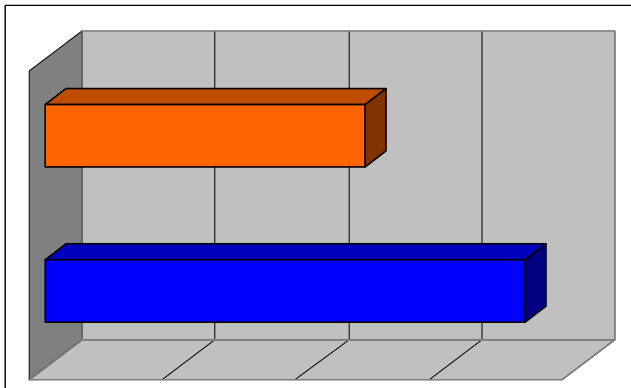
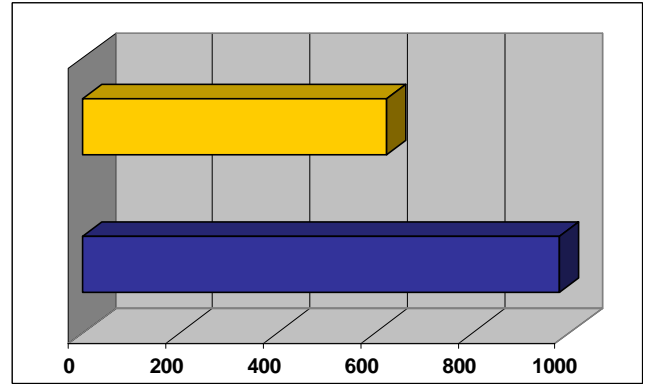
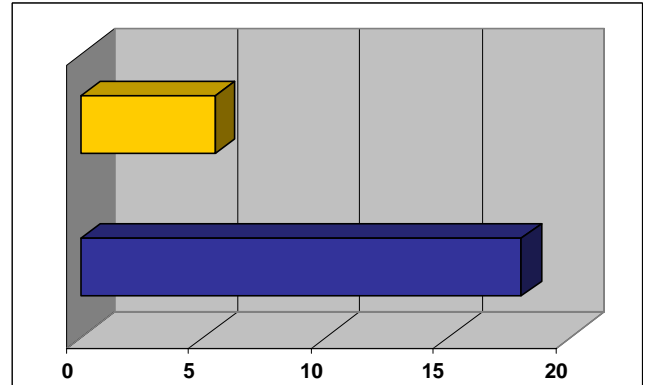


Figure 2 – Lubricant Test Data

4 – Ball Load (kg) – ASTM 2596



Rotary Bearing Test (hrs.) 950 rpm



Temperature Rating (deg. / F)

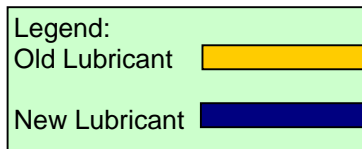
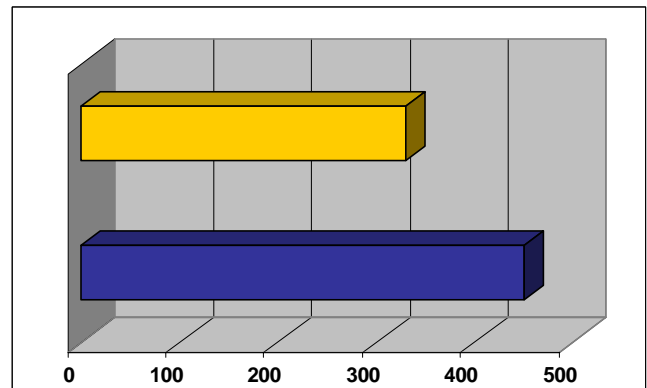
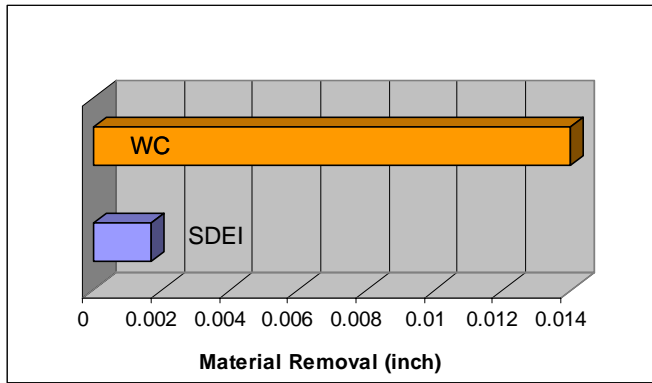
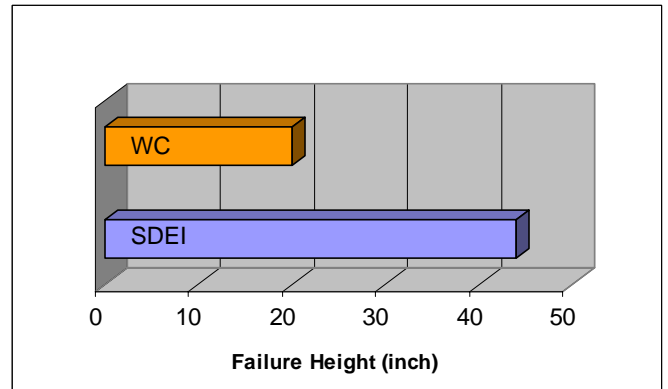


Figure 3 – Test Results: SDEI vs. WC

Abrasion Test



Impact Test



SDEI Insert Geometry



Impact Fixture

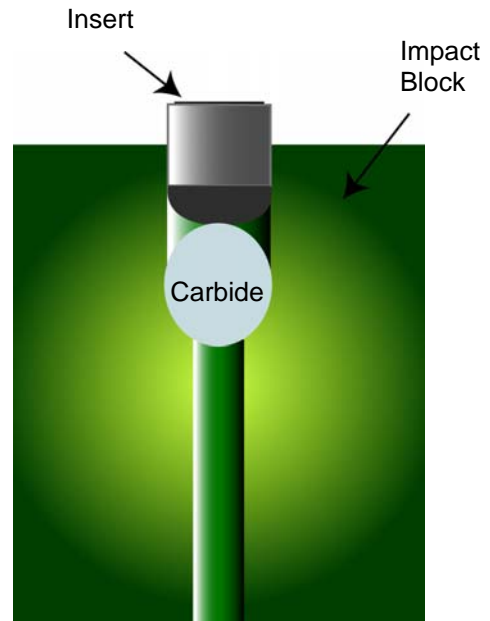


Figure 4 – Assessment Criteria

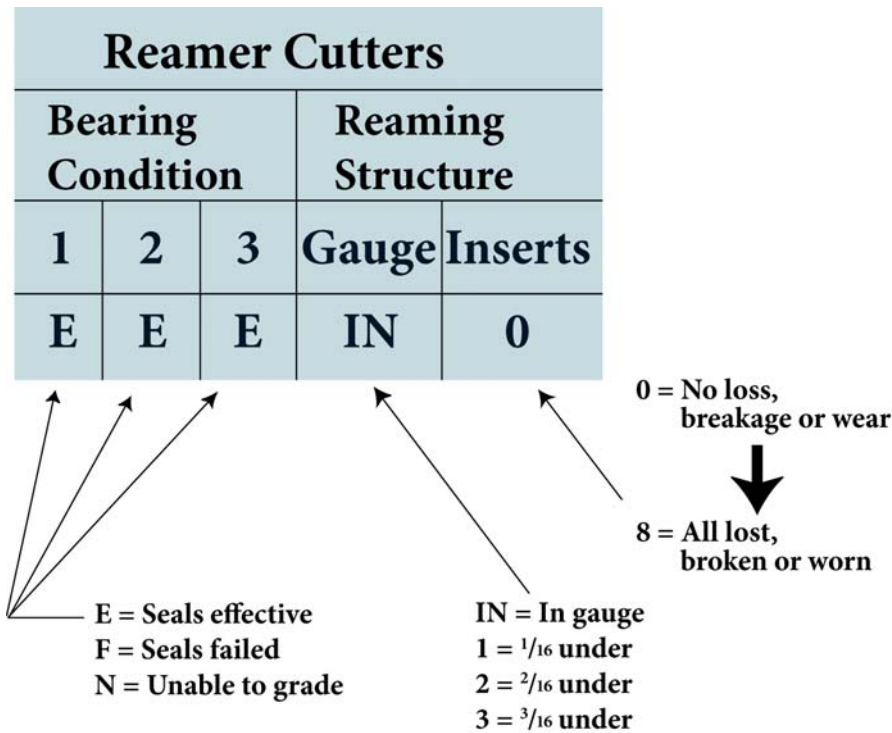


Figure 5 – Validation Test Summary, Case Histories 1 to 3

	Case History 1	Case History 2	Case History 3
Hole Size (in.)	8-1/2	8-1/2	12-1/4
Depth In (ft.)	19,702	9,775	15,610
Depth Out (ft.)	20,937	12,600	17,240
BHA Configuration Summary	Bit - Short Stab - PD M - <i>Reamer</i> - MWD - <i>Reamer</i> - DCs - HWDP - Jar-HWDP - Drillstring Remainder.	Bit - Rotary Steerable System - FEWD - MWD - FEWD - NMDC - NMHWDP - <i>Reamer</i> - NMHWDP - Jar - HWDP - Accelerator - HWDP - Drillstring Remainder.	Bit - Rotary Steerable System - NM Flex - DC - MWD - FEWD - <i>Reamer</i> - Hole Enlarger - XO - BP Valve - NMDC - <i>Reamer</i> - DCs - Jars - DCs - XO - HWDP - Drillstring Remainder.
BHCT (deg. / F)	365	196	260
Drilling Hours	283	89	271.5
Reamer Cutter Revolutions	4,709,314	2,603,696	5,483,214
Dull Cutter Evaluation	E-E-E-IN-0	E-E-F-2-2	E-E-E-1-1
Optional Comments	Reamer in good condition after extended "on-bottom" time. Seal integrity intact after exposure to high circulating temperature. Torque reduced by 35 to 40%.	BHA reached TD in a single run. Well bore gauge was maintained. Slip-stick noted during run. Revolutions on Reamer represents an increase of 24%.	Successful simultaneous drilling and hole enlargement BHA. Reamer is in good condition after extended time period "on-bottom". Torque generated within acceptable levels. No significant shock or vibration.

Figure 6 – BHA Simulation Modeling, Reaction Force Analysis

Case History 2: Reaction Force (Build, Hold and Drop Intervals)

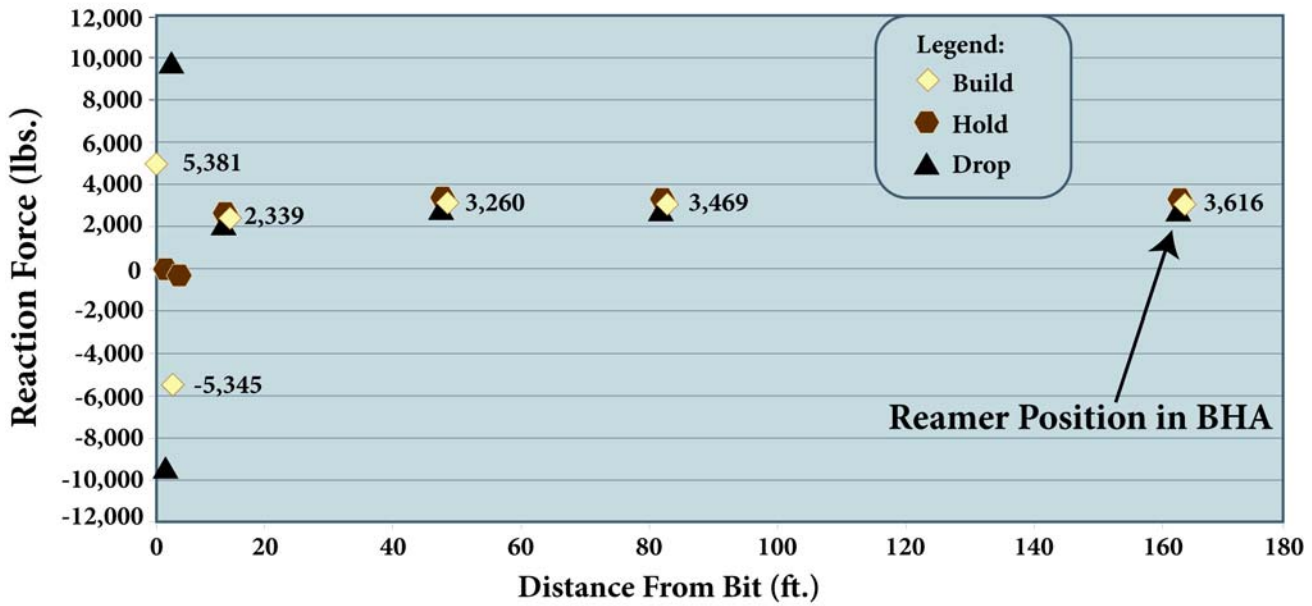


Figure 7 – BHA Simulation Modeling, Bending Stress Analysis

Case History 2: Bending Stress Analysis (Build, Hold and Drop Intervals)

