AADE-15-NTCE-39

PDC Bits Equipped with Rolling Cutters Improve ROP by 34% and Increase Footage by 11% in Texas Panhandle Granite Wash Laterals

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This paper was prepared for presentation at the 2015 AADE National Technical Conference and Exhibition held at the Henry B. Gonzalez Convention Center, San Antonio, Texas, April 8-9, 2015. This conference was sponsored by the American Association of Drilling Engineers. The information presented in this paper does not reflect any position, claim or endorsement made or implied by the American Association of Drilling Engineers, their officers or members. Questions concerning the content of this paper should be directed to the individual(s) listed as author(s) of this work.

Abstract

Efficiently drilling the lateral hole section through the abrasive Granite Wash reservoir sands in the Texas Panhandle creates a unique challenge. The operator is using a steerable motor BHA to drill a lateral section and wanted to increase drilling efficiency by improving PDC bit performance. However, the highly heterogeneous formation was causing inconsistent performance while constructing the 6-1/8" lateral and thus damaging project economics.

A detailed forensic analysis showed extensive cutter damage with abrasive wear being the most common dull characteristic. The cutter wear was causing short runs and frequent trips for bit change-out. To solve the problem required a new approach.

A fixed PDC element creates an inherent limitation because only a small portion of the cutter contacts formation and as the cutter wears drilling efficiency declines. The resulting wear flat generates a high degree of frictional heat which breaks the diamond-to-diamond bond leading to accelerated cutter degradation. The situation is exacerbated by difficulty transferring weight-on-bit due to extended length lateral drilling.

An R&D initiative was launched to investigate different methods to enable a PDC shearing element to fully rotate while drilling to increase overall cutting efficiency and bit life. Engineers investigated several different retention methods and developed a specialized fixed housing which is brazed into the bit blade. The PDC cutter is mounted on a circular shaft and fitted within the housing allowing 360° cutter rotation.

The robust system holds the cutter/shaft assembly securely in the housing for superior reliability. The rolling cutter assembly has essentially the same OD as a standard PDC cutter allowing design flexibility and multiple cutter placement options.

The operator has run PDC bits dressed with rolling cutters in horizontal drilling applications through Granite Wash twelve times. The 6-1/8" R713 bit with rolling cutters have consistently demonstrated their capacity to enhance bit life delivering longer runs at higher ROP. An analysis of the runs compared the rolling cutter equipped bits' average footage and ROPs against the 51 offset runs drilled with fixed cutter PDCs in the same formation and horizontal application. The authors will present two case studies that document performance improvement.

Introduction

The greater Granite Wash play is located in western Oklahoma and the Texas panhandle (**Figure 1**). The eastern edge of the Granite Wash fairway is in western Oklahoma's Washita, Beckham and Roger Mills counties where it is known as the Colony Wash. As the play trends west, the formation is called the Texas Panhandle Granite Wash where drilling activity is primarily focused in Wheeler, Hemphill and Roberts counties.

The term Granite Wash (GW) is the nomenclature applied to the sequence of sediments that produce oil, liquids-rich natural gas condensate in addition to dry gas from Des Moines, Cherokee and the Atokan age formations. The thick sequence of stacked formations is the product of sediment-laden runoff caused by erosion of the ancestral Wichita/Amarillo Uplift which was then deposited as turbidite fans in a deep-water environment.

Optimization Objectives

In most cases, the operator is developing its Granite Wash prospects using a steerable motor BHA to drill a long lateral borehole to increase reservoir exposure and wanted to increase drilling efficiency by improving bit life. The area can be economically attractive with consistently good lateral performance.

However, bit life and performance in the lateral was inconsistent across the field which was eventually attributed to formation heterogeneity. The inconsistent performance was causing frequent bit trips, short runs and rapid cutter wear in the gauge wear. The economics of each individual project would be greatly improved if the operator could increase PDC bit life in the areas where they expected poor performance.

Wear Mechanism/Rolling Cutter

To accomplish the objectives the industry has been working to improve PDC cutter/bit performance.[1-6] In 2003, a leaching process was introduced to enhance thermal stability which improved abrasion resistance.[7] Further studies concentrated on determining the damaging effects of frictional heat at the cutting edge. This extreme temperature causes accelerated cutter wear, especially in non-leached cutters. More wear generates more heating. More heating induces more wear. To break this cycle, it is critical to keep the cutting tip sharp and cool. If a mechanism could be implemented to evenly spread wear over the full cutting edge, bit life would be significantly increased. Such a device would allow the cutter to remain sharp for extended run lengths. This could be achieved if the cutters are rotating while shearing formation. Rotation would evenly distribute wear and also effectively cool the cutter thus increasing service life.

Extensive FEA-based modeling was performed along with comprehensive laboratory testing to validate the concept of a fully rotating PDC shearing element. Field testing of this new type rolling cutter showed that cutter life could be extended to deliver improved bit durability (**Figure 2**). The results of the modeling studies, laboratory work and initial field test results can be reviewed in previous SPE publications.[8-10]

Rock Strength/Lithology Analysis

To gain insight into the nature of the Granite Wash formation, engineers used a rock strength analysis system to quantitatively determine the formation's unconfined compressive strength (UCMPS). The formations shown in **Figure 3,** between the approximate depth range of 11,200ft to 12,900ft, are from a vertical well drilled in Wheeler County, Texas. The analysis revealed the GW has an unconfined compressive strength varying from 10,000psi to 15,000psi with occasional hard streaks up to 20,000psi. The formation abrasion index shows heavy abrasivity with normal to moderate impact levels.

A separate petrologic evaluation revealed the Granite Wash is composed mainly of quartz, feldspar with quartz/calcite cementation. By combining this knowledge with the UCMPS data, engineers determined the Granite Wash play would be ideal for testing the rolling cutter's resistance to abrasive wear.

To assess how bits equipped with rolling cutters have improved performance in the operator's GW prospects, two case studies are offered below.

Rolling Cutter vs Fixed Cutter (Case Study 1)

The Granite Wash play has proven to be an ideal opportunity to test, learn and develop PDC bits equipped with rotating cutters. To date, rolling cutter PDCs have been run over 265 times in a Granite Wash application and continue to deliver excellent performance and value. Sabine O&G has run over 20 rolling cutter bits in their Granite Wash applications. The data set for Case Study 1 is composed of the operator's 6-1/8" lateral runs with depths in greater than 8700ft with within a four mile radius in northwest Roberts County Texas during 2014 (**Figure 4**).

A depth in of greater than 8700ft was used in order to remove bits that drilled the curve section from the data set. Short runs with reasons pulled other than penetration rate were also excluded. The analysis includes just bits that drilled at least 400ft as this was the shortest bit run pulled for penetration rate. The query narrowed the data set down to 18 laterals drilled with 51 bit runs by four different rigs. Twelve of those runs were drilled with rolling cutter equipped bits with the remaining 39 being fixed cutter bit runs.

The data set is shown in **Figure 5** as a function of penetration rate and footage for individual bit runs with the average ROP and footage for both rolling cutter and fixed cutter bits being plotted. Twelve rolling cutter bit runs averaged 1411ft drilled at an ROP of 31.7ft/hr. The data set containing the 39 fixed cutter bit runs averaged 1268ft drilled at an ROP of 23.7ft/hr. Calculations revealed the rolling cutter bit runs were on average 11% longer and 34% faster than the average fixed cutter bit runs.

The data set is also shown as a function of penetration rate and footage for each individual bit run with the median ROP and footage for both rolling cutter and fixed cutter bits (**Figure 6**). The median of the 12 rolling cutter bits run was 33.5ft/hr and 1378ft drilled. The median of the 39 fixed cutter bits was 20.9ft/hr and 1152ft drilled. The median value of the 12 rolling cutter bit runs was 20% farther and 61% faster than the median value of the 39 fixed cutter bit runs.

An economic analysis of the cost per foot (CPF) was performed to demonstrate the capability of rolling cutter bits to reducing drilling costs. CPF was calculated for the average rolling cutter and fixed cutter bits by assuming a constant bit cost of $20,000USD and a daily rig cost excluding the bit price of $60,000/day ($2,500/hr).

$$\boldsymbol{CPF} = \frac{(Bit\ Cost + (Rig\ Rate * Bit\ Run\ Hours))}{Bit\ Run\ Footage}$$

$$\boldsymbol{Bit\ Run\ Hours} = \frac{Footage}{ROP}$$

$$\boldsymbol{Average\ Rolling\ Cutter\ CPF} = \frac{(\$20{,}000 + (\$2{,}500\ per\ hour * 44.5\ Hours))}{1411\ feet} = \$93.04\ per\ foot$$

$$\boldsymbol{Average\ Fixed\ Cutter\ CPF} = \frac{(\$20{,}000 + (\$2{,}500\ per\ hour * 53.5\ Hours))}{1268\ feet} = \$121.39\ per\ foot$$

The calculations showed the average rolling cutter equipped bit was 23% more cost efficient. Cost per foot was also calculated for the median rolling cutter versus fixed cutter bits using the following equations.

$$\boldsymbol{CPF} = \frac{(Bit\ Cost + (Rig\ Rate * Bit\ Run\ Hours))}{Bit\ Run\ Footage}$$

$$\boldsymbol{Median\ Rolling\ Cutter\ CPF}$$
$$= \frac{(\$20{,}000 + (\$2{,}500\ per\ hour * 41.1\ Hours))}{1378\ feet}$$
$$= \$89.14\ per\ foot$$
$$\boldsymbol{Median\ Fixed\ Cutter\ CPF}$$
$$= \frac{(\$20{,}000 + (\$2{,}500\ per\ hour * 55.1\ Hours))}{1152\ feet}$$
$$= \$136.98\ per\ foot$$

The median rolling cutter bit was 35% more cost efficient than the PDC bits equipped with fixed cutters.

Rolling Cutter vs Fixed Cutter (Case Study 2)

The operator drilled part of a Granite Wash lateral with two bits which had identical blade count and cutting structure with the exception that one was equipped with rolling cutters and the other with only fixed cutters. The rolling cutter bit drilled 2546ft in 70.0hrs for an ROP of 36.4ft/hr. It was followed with the fixed cutter bit which drilled 2216ft in 73.5 hours for an ROP of 30.2ft/hr.

A picture of the dull condition of the rolling cutter equipped bit is compared with the fixed cutter bit in **Figure 7**. The pictures show the rolling cutter has evenly distributed circumferential wear but the fixed cutter suffered a significant wear flat. Both bits drilled similar footage but the rolling cutter drilled 17% faster than the fixed cutter bit. Cost/ft comparison documents the value added by utilizing PDC bits with rolling cutter technology.

$$\boldsymbol{Rolling\ Cutter\ CPF}$$
$$= \frac{(\$20{,}000 + (\$2{,}500\ per\ hour * 70.0\ Hours))}{2546\ feet}$$
$$= \$76.59\ per\ foot$$
$$\boldsymbol{Fixed\ Cutter\ CPF}$$
$$= \frac{(\$20{,}000 + (\$2{,}500\ per\ hour * 73.5\ Hours))}{2216\ feet}$$
$$= \$91.94\ per\ foot$$

Conclusions

The operator has run PDC bits equipped with rolling cutters in horizontal applications through the abrasive Granite Wash 12 times out of a total 51 lateral bit runs. The rolling cutter bits have consistently demonstrated their capacity to significantly enhance bit life delivering longer runs at competitive ROPs compared to offsets drilled with fix cutter PDC bits.

An engineering analysis of the 12 runs compared the rolling cutter equipped R713 average and median performance totals against 39 offset runs drilled with fixed cutter PDC bits, in the same horizontal application. Also a back-to-back bit run case study using the same bit design, one with rolling cutters and one with fixed cutters in the same lateral was also examined. The analysis revealed the RC bits drilled 11% more footage (1411ft) compared to fixed cutter PDC bits (1268ft) with a 34% higher ROP (31.7ft/hr) then the fixed cutter bits (23.7ft/hr). The average rolling cutter bit was 23% more cost efficient. The median rolling cutter bit was 35% more cost efficient than the fixed cutter bits.

Case Study 2 showed the rolling cutter bits were 17% faster, more cost efficient and were pulled in better dull condition than the fixed cutter bits when drilling similar footage in the same lateral back-to-back. The rolling cutters ability to stay sharp and distribute wear around the circumference enabled the bit to drill more efficiently than the fixed cutter bit reducing cost/foot.

Acknowledgements

The authors want to express their gratitude to management at Sabine Oil and Gas and Smith Bits, a Schlumberger Company for permission to release the field performance, well data and bit development process. Finally, thanks go to Craig Fleming, Smith Bits for his technical writing and editorial contributions.

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Appendix (Maximum and Average Calculations for Case Study 1 and Case Study 2)

Rolling Cutter Bits (12 Bits)					
	Depth In (Feet)	Depth Out (Feet)	Drilled (Feet)	Hours	ROP (feet per hour)
Max	11630	12470	2546	75.30	48.59
75%	10132	11678	1521	53.38	35.90
Med	9753	11353	1378	45.40	33.52
25%	9024	10192	1121	38.25	24.27
Min	8710	9831	840	23.50	20.36
Avg	9685	11096	1411	46.76	31.70
Std Dev	812	875	423	14.88	8.47

Fixed Cutter Bits (39 Bits)					
	Depth In (Feet)	Depth Out (Feet)	Drilled (Feet)	Hours	ROP (feet per hour)
Max	13241	14436	2433	134.00	51.87
75%	11387	12616	1558	73.50	25.95
Med	10349	11632	1152	52.50	20.87
25%	9770	11069	907	42.50	18.25
Min	8757	9845	417	10.50	10.79
Avg	10607	11875	1268	58.27	23.67
Std Dev	1123	1327	520	27.03	8.25

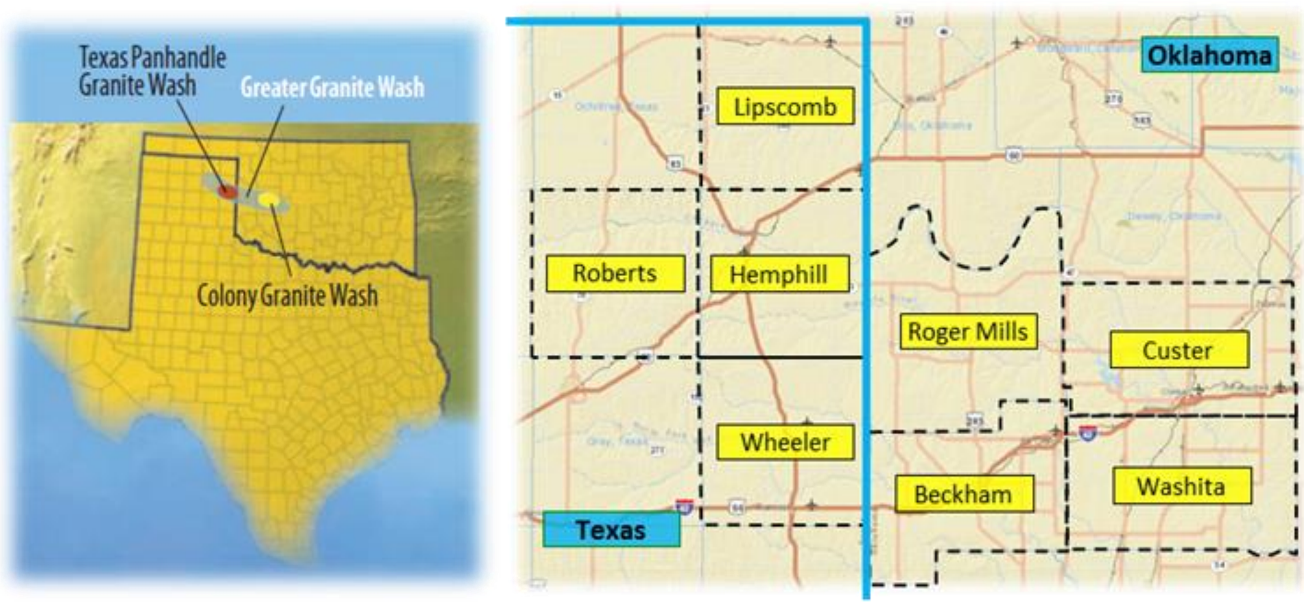

Figure 1 – General outline of Granite Wash fairway with county identification map

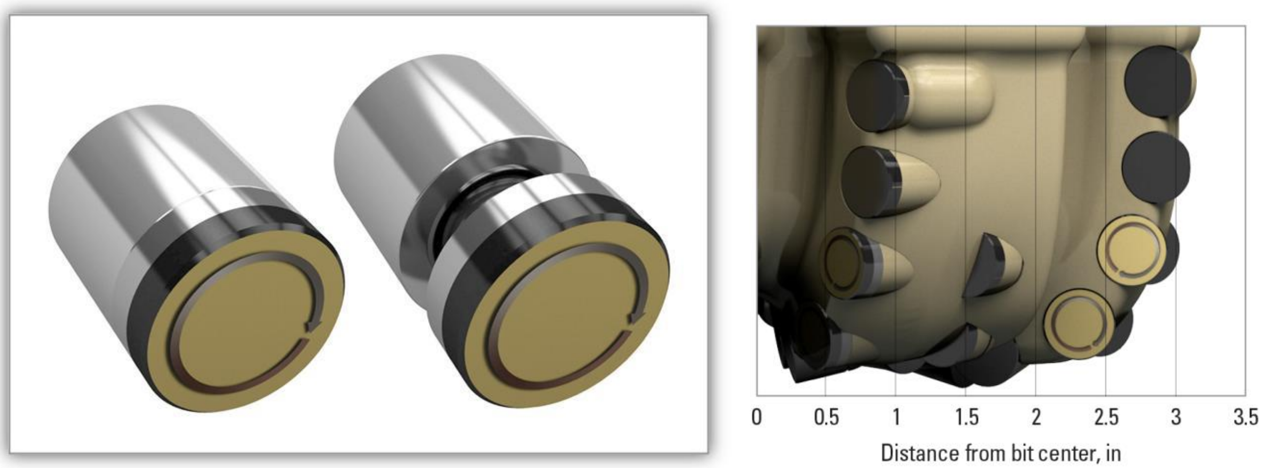

Figure 2 – Innovative housing design secures the cutter and enables full 360° rotation (left)
The rolling cutters are strategically positioned in the high wear shoulder area to improve bit durability

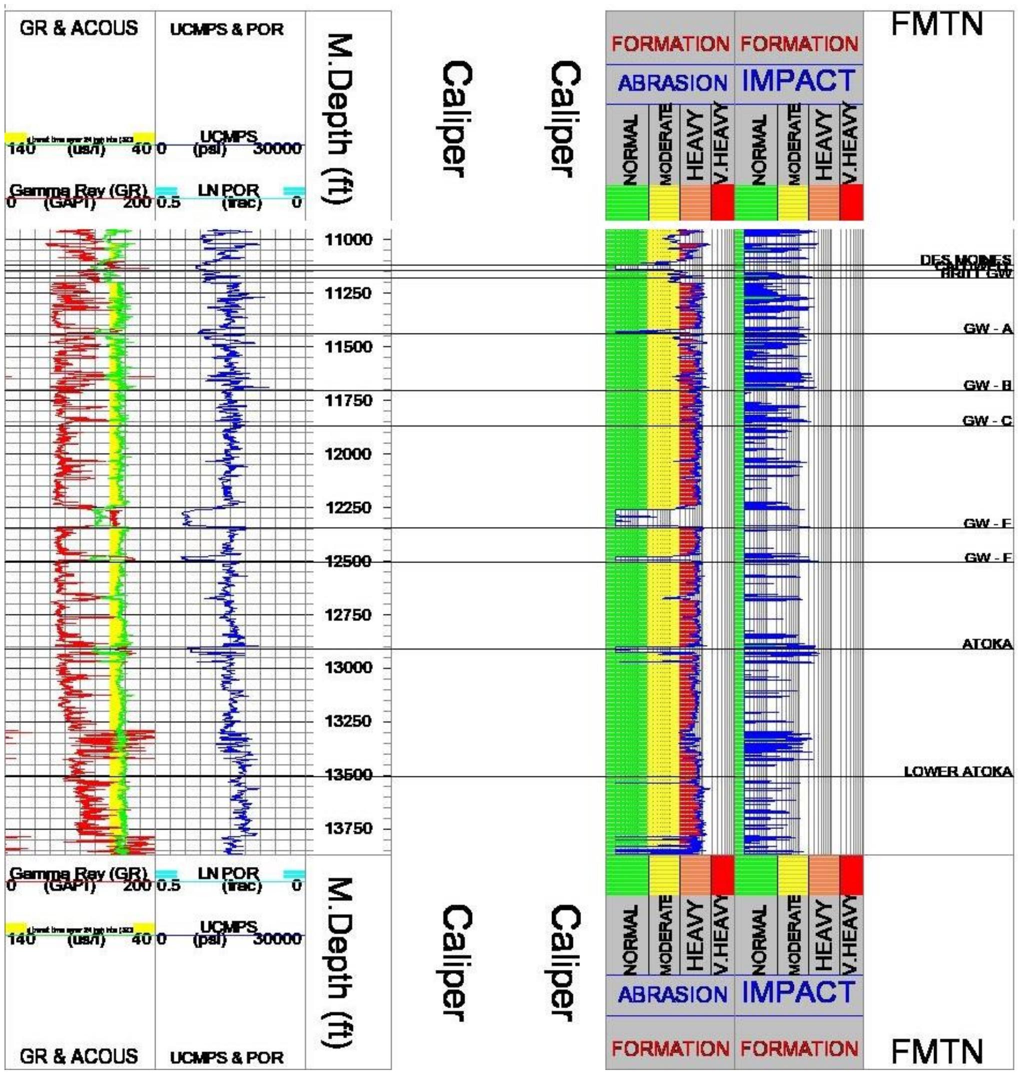

Figure 3 – Lithology of Granite Wash with associated UCMPS values derived from sonic and gamma ray logs

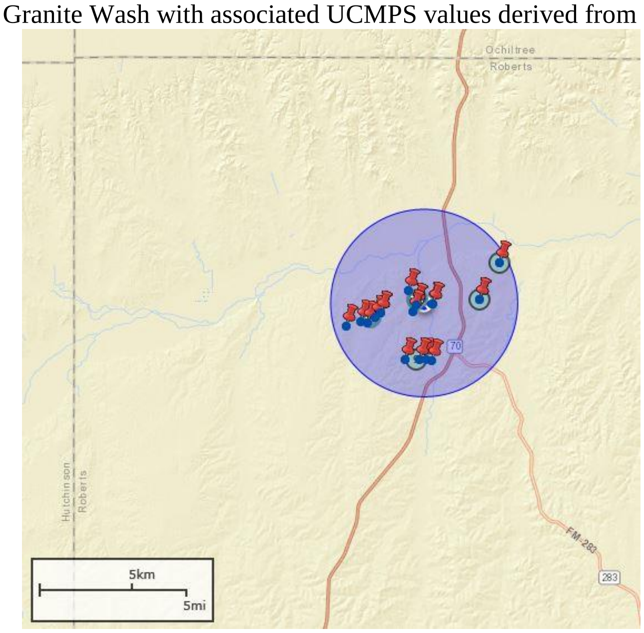

Figure 4 – Specific location map Case Study 1 and 2 northwest Roberts County, Texas

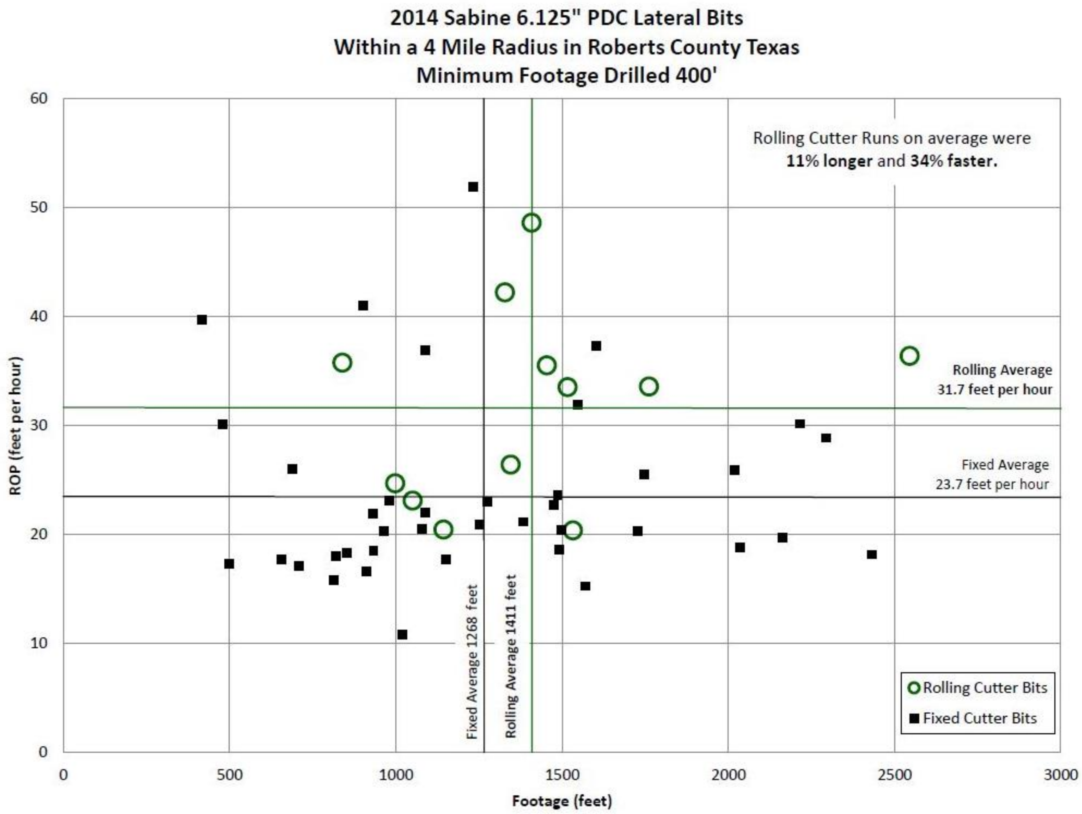

Figure 5 – PDC bits with rolling cutters drilled 11% more formation 34% faster on average than bits equipped with fixed shearing elements.

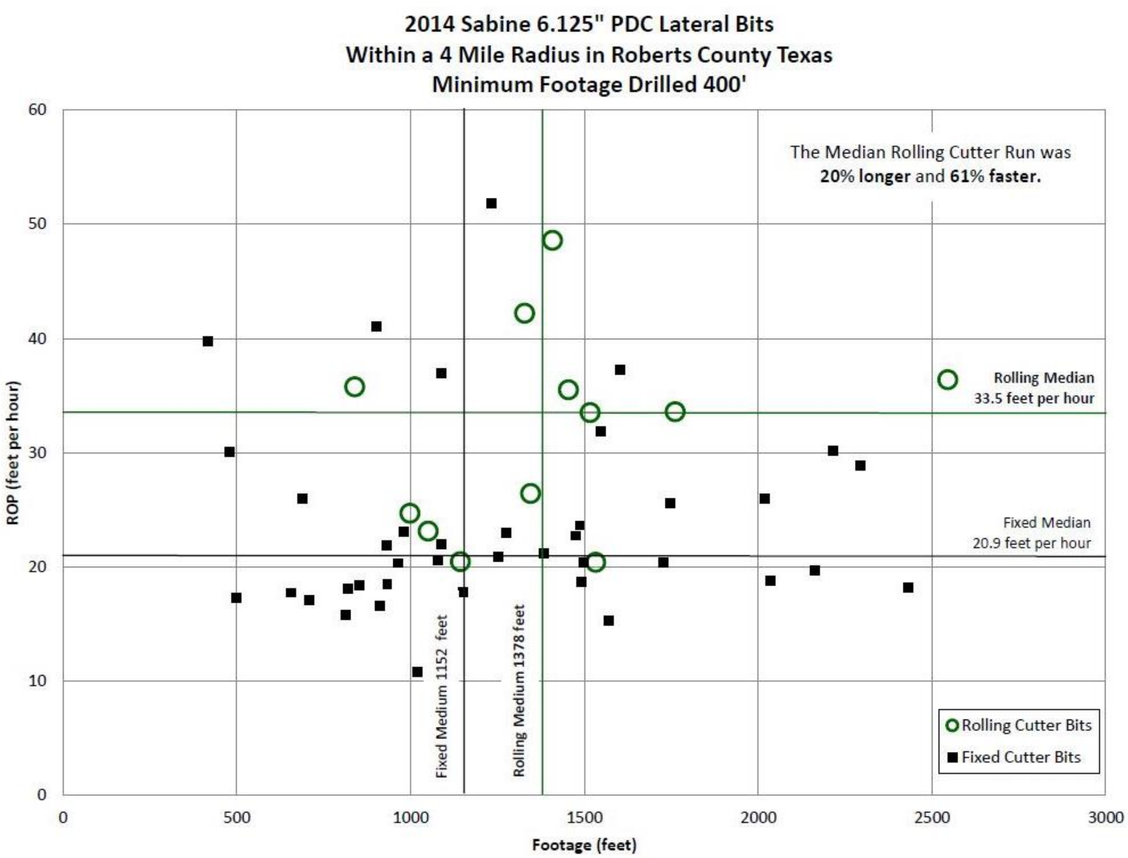

Figure 6 - PDC bits with rolling cutters drilled 20% more formation 61% faster on median than bits equipped with fixed shearing elements.

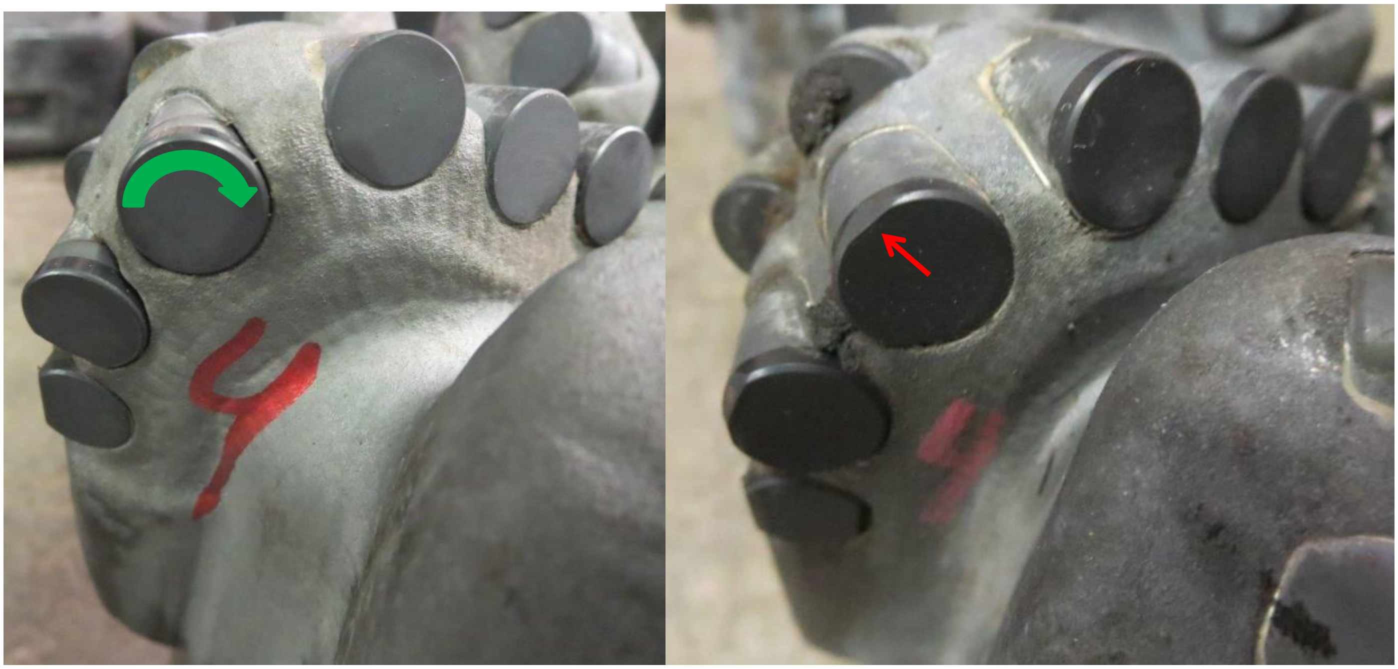

Figure 7 – Dull comparison for Case Study 2. The green arrow shows the distributed wear while the red arrow shows the wear flat generated on the fixed cutter.