

Roller Cone Bit Wear Resistance in Abrasive, High Angle, and Lateral Applications Addressed with Shirrtail Protection Technology

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Abstract

Complex wellbore geometries and abrasive formations impose much greater wear demands on roller cone drill bits and result in shorter bit life and reduced penetration rates. A technology has been developed to specifically protect vulnerable shirrtail areas.

In abrasive, high angle, and lateral applications, a common dull mode is wear to the shirrtail edge. When drilling curves and lateral applications, shirrtail wear often leads to exposure and eventual failure of the seal or bearing.

This paper is the first published review of patented technology for the placement of hard, wear resistant pucks to vulnerable areas of the shirrtail, including the leading and lower edges, of non-sealed and sealed bearing roller cone bits. Design, materials, and manufacturing aspects of bit development are discussed, and dull modes in abrasive, high angle, and lateral applications are examined and contrasted. Case history field data details performance in several applications.

Introduction

Horizontal drilling and building curves in abrasive formations place additional demands on the bit body. With roller cone drill bits, wear to the shirrtail edge is a common dull mode in these high angle, and lateral applications. This wear from fluid and cuttings, particularly on the leading edge, often leads to exposure and eventual failure of the seal or bearing. (Fig. 1)

Various methods have been proposed and applied to slow and prevent this wear but shirrtail protection, in particular along vulnerable edges, has not been fully addressed and wear continues to shorten bit life resulting in costly trips.

These methods have typically involved hardfacing, tungsten carbide inserts, or a combination of the two. In contrast, a patented technology allows wear-resistant tungsten carbide pucks to be strategically positioned in slots on the shirrtail. In the Mississippi Lime formation in northern Oklahoma and southern Kansas, a direct comparison of roller

cone drill bits with and without the new shirrtail protection technology shows reduced wear and improved bearing life. Drilling in Canadian SAGD heavy oil applications also shows similar performance.

Conventional Shirrtail Wear Mitigation

Prior industry efforts to delay shirrtail wear include welded hardfacing material applied along a portion of the shirrtail. This is typically done with a nickel- or steel-based weld rod filled with pelletized tungsten carbide. In highly abrasive formations, the hardfacing can wear quickly due to the relatively poor performance of the welding medium, which makes up the majority of the hardfacing material.

Tungsten carbide inserts (TCI) are also used to protect the shirrtail. The inserts provide better abrasion resistance than the welded hardfacing material, but because they are located at a distance from the thinner shirrtail edge to allow for press fitting, they are less effective at protecting the critical area near the seal. (Fig. 2)

Combinations of hard facing and inserts were applied to reduce the cost of drilling straight hole with curved sections in Canadian wells. Buske et al. (2008)¹ describes the use of roller cone bits with inserts and hardfacing in highly abrasive conditions. It was noted that the roller cone bits were typically removed from service because of damage or wear to the bearings or seals, and/or to the cutting structures. This damage was attributed to weakness in the leg section. The wear was first addressed with tungsten carbide inserts, which improved performance. But the softer portion of the leg OD (shirrtail) remained exposed due to spacing between the tungsten carbide inserts and concern about the insert holes creating crack-propagation points. To improve leg durability and increase seal and bearing reliability, abrasion-resistant hardfacing was incorporated onto the majority of the leg OD.

In Canadian SAGD applications, bits of all designs required custom features to combat the highly abrasive sands when steering. (Okusanya et al. 2007)² Rotating and/or sliding through cutting beds of coarse, abrasive sand particles required tungsten carbide inserts and hardfacing wear pads

and shirrtail protection to combat gage and shirrtail wear. Elastomer or metal-face seals were also enhanced to prevent sand encroachment on the bearings during motor drilling.

Seal failure as well as gauge and shirrtail wear with conventional TCI roller cone drill bits increases in tough interbedded formations of hard sandstone, siltstone, shale, and chert. The conditions encountered in directional drilling applications accelerated cutting structure breakdown and caused hole-wall contact. (Olson et al. 2008)³ Wear was addressed with enhanced OD and leg protection to ensure bearing integrity and gauge-holding ability, and stronger materials and processes to withstand high cyclic loading of directional drilling. This involved alterations in insert position and materials, as well as hardfacing.

Solid Tungsten Carbide “Pucks” for Wear Mitigation

Protection technology has been developed that places hard, wear resistant pucks on the shirrtail edge of sealed and non-sealed bearing roller cone bits. (Fig. 3) The custom-fitted hardmetal puck is typically made of solid tungsten carbide, but can also be formed of an impregnated diamond segment or a polycrystalline cubic boron nitride compact.

The tungsten carbide puck is superior to the traditional weld on tungsten carbide hardfacing because it is denser and not as susceptible to abrasion and erosion. While welded hardmetal carbide content is typically 65-67%, the pucks are 86-92% carbide. The grade of the pucks was selected to provide a balance of abrasion resistance and toughness because this area can experience impact with the hole wall depending on the drilling conditions.

In manufacturing, the preformed pucks are set in milled slots in the edge of the shirrtail and brazed in place with flowable silver alloy filler. Incorporating the pucks into the finished product requires special care because of the heat applied near the surfaces where the seal and bearing reside.

The slots formed for the pucks are significantly shallower than what would be required to hold a TCI insert in place. The puck is shaped to conform to the geometry of the shirrtail and is typically higher than the outer surface and slightly exposed. Its radius is designed to match the radius of the shirrtail tip, and the puck's contour matches the shirrtail contour. As a result, multiple pucks have been created to match various bit sizes. (Fig. 4)

Field Studies

The tungsten carbide puck shirrtail protection was initially used in Canada to address wear problems and bit life in abrasive SAGD oil sands applications. More recently it has been used in Oklahoma and Kansas to drill horizontal wellbores in the Mississippi Lime formation's tough lime and chert.

Mississippi Lime

In Mississippi Lime drilling, a study of 6.125-in. roller cone bits used to drill the lateral section was conducted to directly compare bit performance with and without shirrtail edge protection. Presented are bit run data for three IADC 637 roller cone bits with welded hardfacing shirrtail protection and three IADC 637 bits with the puck shirrtail protection. The bits are made by the same manufacturer and had very similar cutting structures. All the bits were run under similar conditions at well sites within a 14-mile radius. (Fig. 5)

The drilling environment of the Mississippi Lime formation in northern Oklahoma and southern Kansas was one of the focus areas for development of the shirrtail protection technology. Horizontal drilling of the 6 1/8-in. hole is typically done with a PDC bit. However, it is not uncommon to encounter chert in this formation. Often, when a PDC bit has been heavily damaged or rig personnel have noted a significant presence of chert in the cuttings, the PDC bit is pulled and a roller cone bit is run. Roller cone bits are typically run through this section with 30 to 35-klb weight on bit and at 150-240 rpm or more on a bent housing motor.

Field observations revealed that gage and shirrtail damage grew in severity as the chert percentage increased. With a traditional shirrtail design, the welded hardmetal wears severely to expose the parent steel. This increases the wear rate toward the seal gland, which leads to seal and bearing failure.

All bits drilled through a varying percentage of chert. One bit was reported to have drilled through intervals that logged as much as 90% chert. The bits run with shirrtail protection pucks show a significant improvement in dull condition. (Fig. 6 through Fig. 11)

The dull condition is affected by varying levels of chert content in the well. Therefore, damage is proportional to the amount of chert drilled, the amount of reaming from prior runs, and the amount of directional drilling that took place. In these tests, the runs with carbide puck shirrtail protection drastically improved dull condition compared to standard designs.

Heavy Oil Wells in Canada

When drilling through the 12 1/4-in. curve section in the heavy oil applications of Northern Alberta, Canada, the formation is very soft but very abrasive. The increased side loading from the directional drilling along with hydraulic effects puts extra stresses on the shirrtail area of the bit. Bits are typically run through this interval with 20-40 klb weight on bit and rotated by a bent housing motor at 80-200 RPM. As formation is drilled, cuttings become entrained in the fluid and wash over the tip of the shirrtail. In this application, bits are typically run twice before being removed from service due to excessive gage and shirrtail damage.

When the puck protection was added to the shirrtail of the IADC 437 bits, the dull condition improved dramatically. The carbide pucks came out in good shape and allowed bits to be run three or four times before being removed from service. (Fig. 12 through Fig. 14)

2008.

Conclusions

Placement of hard, wear resistant pucks on the vulnerable areas of the shirrtail of roller cone bits has significantly improved wear mitigation in abrasive, high angle and lateral applications. The solid tungsten carbide pucks are harder than conventional welded hardmetal and, unlike tungsten carbide inserts, they can be applied to the leading and lower edges of the shirrtail where wear can lead to seal and bearing failure.

Experience in high chert Mississippi Lime formations in Oklahoma and Kansas, and in Canadian SAGD oil sands applications has shown that bits fitted with the pucks outperformed similar offset bits, which lacked the feature. Bit wear and failure has been reduced to allow multiple runs in the challenging applications. In addition to increasing bit life, the feature reduces overall drilling costs by reducing non-productive time to trip dull or failed bits.

Acknowledgments

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Nomenclature

SAGD = Steam Assisted Gravity Drainage

ROP = Rate of Penetration

RPM = Revolutions Per Minute

PDC = Polycrystalline Diamond Compact

OD = Outer Diameter

TCI = Tungsten Carbide Insert

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Fig. 1 - Common shirttail edge dull mode

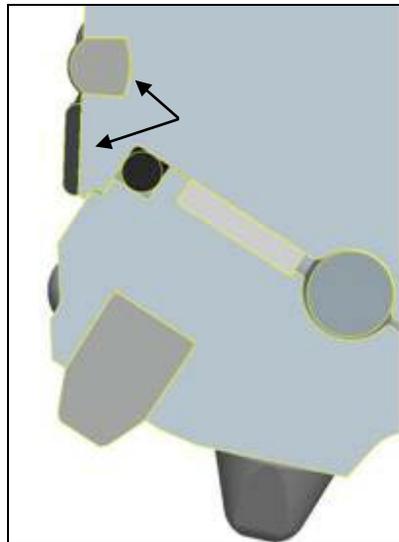


Fig. 2 - Traditional hardmetal and insert configuration

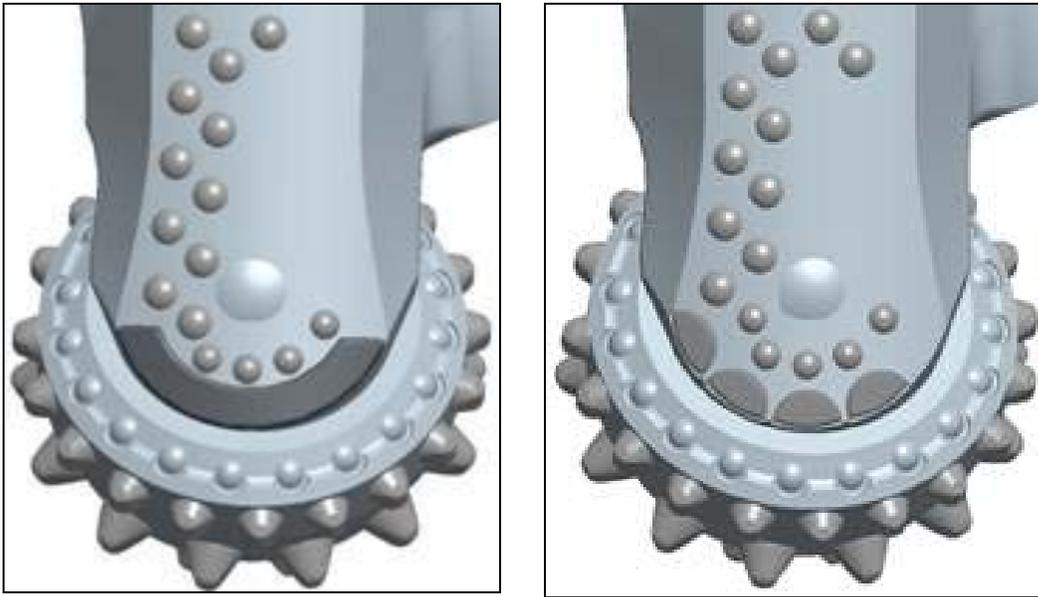


Fig. 3 - Placement of carbide pucks



Fig. 4 - Preformed tungsten carbide puck

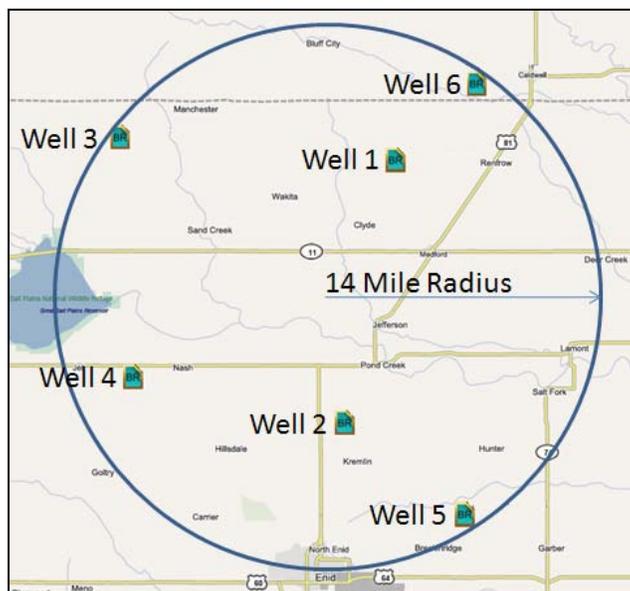


Fig. 5 - Study area

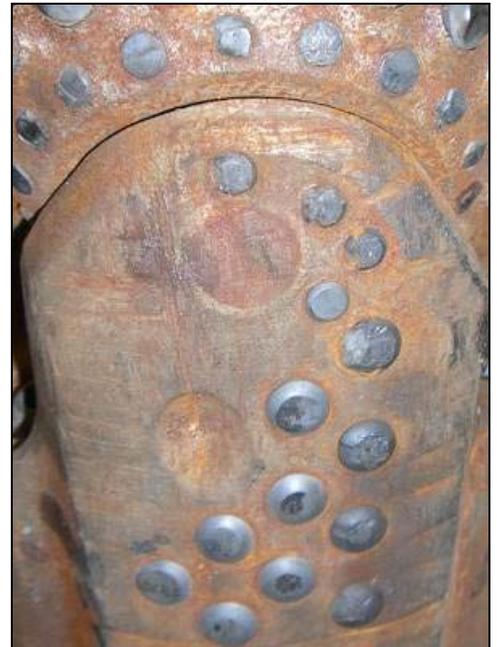
Bits with conventional welded hardfacing shirrtail edge protection



**Fig. 6 - Well 1: Moderate chert
423 ft drilled**



**Fig. 7 - Well 2: Light chert
820 ft drilled**

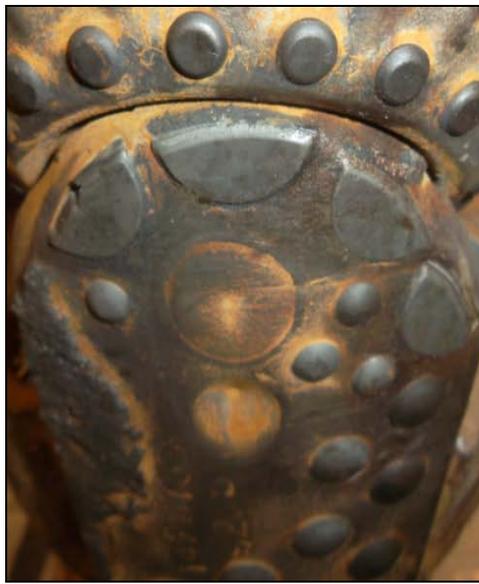


**Fig. 8 - Well 3: Moderate chert
763 ft drilled**

Bits with shirrtail edge protection pucks



**Fig. 9 - Well 4: Moderate chert
441 ft drilled**



**Fig. 10 - Well 5: High chert
561 ft drilled**



**Fig. 11 - Well 6: Very high chert
667 ft drilled**



**Fig. 12 - Bit #1 after one run
1,686 ft (514m)**



**Fig. 13 - Bit #2 after one run
1,578 ft (480m)**



**Fig. 14 - Bit #3 after fourth run
6,670 ft (2,033m) accumulated**