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Diamond Enhanced Hammer Bit Impacts Drilling Peformance in the Val Verde Basin

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Abstract

Diamond Enhanced Hammer Bits in conjunction with Down-the-Hole Air Hammers have been utilized throughout the 1990's to improve penetration rates in hard formations as well as to reduce deviation and improve overall drilling costs. Significant improvements in bit life have been made by utilizing the 3rd Generation Impax Hammer Bits along with the current Best Drilling Practices that have been developed in the Val Verde Basin. This paper will review these Best Drilling Practices as well as discuss the new technology that was developed for these Percussion Drilling applications.

Introduction

Conventional air hammers and Diamond Enhanced hammer bits (Impax bits) have been used in the oilfield since 1988, and were the first successful bit applications for shaped Diamond Enhanced Insert technology (US Patent # 4,729,440). Impax bits quickly proved to be cost effective over conventional tungsten carbide (WC) hammer bits due to the extended cutting structure life.' This improvement in bit cutting structure life has increased the average footage per bit drilled in abrasive formations from 100% to as much as 500% with a corresponding increase in hours.

Such a dramatic increase in bit life will often uncover other component limitations. In this case, the increase in the cutting structure life resulted in an increase in bit body fatigue failures known as bit "shankage". Bit shankage is the separation of the Bit Head from the Bit Spline (shank), and results in a Lost-In-Hole situation or a fishing job to retrieve the bit head. In mining and water well applications, this type of failure does not present a big problem because of the shallow hole depths. However, when drilling for oil or gas at depths of 13,000 feet or more, a fishing job can be extremely expensive.

The first efforts to reduce the chance of a fishing job due to bit shankage was to limit the bit life to 60 hours. This lowered the number of shanked bit considerably, but did not solve the problem. During the next two years, much effort was put into improving the quality of the bit body material. The results of the work suggested a bit body material change from 4340 steel to using forgings made of "Aircraft" quality 6418 "Hy-Tuf' steel. The improved quality of the steel did help improve the average fatigue hours and reduce the number of shanked bits but again the problem was still not solved, and many customers were still limiting the bit runs to 60 hours to minimize the chance of a fishing job.

In many cases, the bits with 60 hours were pulled out of the hole with the diamond inserts in good to excellent condition which suggests that the operator or drilling contractor was not getting the full use of the hammer bits.

Finally in 1991, with the design of the Hammer Bit Retaining System (US Patent # 5,065,827 – Figure 1), the chance of these Lost-in-Hole situations was minimized by retrieving the bit head when tripping the drill string for a bit body fatigue failure. This system incorporates the use of a sleeve that is machined as a mating component to the hammer's driver-sub. The retainer sleeve is also attached to the bit by a "fishing" thread but at the same time allows the hammer to operate in its typical on-off bottom operating conditions. In order to maintain the on-off bottom operating conditions, the bit head had to be increased in length which again called for unique forgings. The Retaining System has virtually eliminated the chance of fishing jobs to retrieve bit heads due to fatigue failures. It has also made a dramatic impact on the average number of hours that hammer bits are run downhole (60 –> 100+ hours). Thus, since 1992, Impax hammer bits have been run until the full life of the bit has been exhausted, and without the concern for lost-in-hole situations.

3rd Generation Impax Hammer Bit

With the above problems solved, the major failure mode of Impax hammer bits became gage row insert breakage. With the quality of the bit and diamond insert manufacturing process verified, the failure mode suggested that the diamond inserts may have either reached its fatigue life or that the impact loads of the hammers were now exceeding the capability of the inserts. In either case, the failure mode suggested that a "tougher" Impax bit was required to improve the total footage per bit.

The 3rd generation of the Impax hammer bits have significantly increased the total footage drilled per bit. In 8 ¾" hole size, the 3rd generation Impax hammer bit has drilled an average of 3927 feet[2] in 66 hours in Terrell County, TX.. This is a 73% improvement over the 2nd generation H45 design's (Figure 2) 2271 feet with nearly the same rate of penetration (60 feet/hour). This same Impax hammer bit (8 ¾" H42R8R3PD; Figure 3) will often drill 5000 feet or more in the Pakenham, Geaslin, and Brown Bassett Fields and also holds the World Record for single run footage with a hammer bit in nearby Crocket County with 8258 feet in 110 hours (75 feet per hour). To accomplish this dramatic increase in bit performance, there were three major design improvements incorporated:

1. Improved cutting structure;
2. Larger diamond inserts on gage;
3. Tougher diamond composition;

The H42R8R3PD Impax hammer bit's cutting structure changes included a slightly more rounded profile (stronger), heavier gage insert count (tougher) and three air exhaust ports (improved cleaning). However, by keeping a similar total insert count, this design allowed the same impact energy per insert but put more total energy at the gage row.

At the heart of this unique bit design is the large (22mm – Figure 4) diamond enhanced inserts on the gage row which replaced the conventional 18mm / ¾" diamond insert. The size increase translates to a 36% increase in area but delivers a much more significant impact strength improvement of 86 %. This new insert also came with a tougher diamond grade which resists impact breakage but allows the diamond to slowly wear. The increase in toughness has been documented in lab test results to improve fatigue strength by as much as 54%. The overall improvement in impact strength, along with the cutting structure design changes have changed the failure mode of the gage row from insert breakage to a consistent gage wear pattern (Fig. *5)*.

Best Drilling Practices

Along with the improved bit design, field operations have made improvements which can be documented as "Best Drilling Practices" for percussion applications in Terrell County. Although each well is different and adjustments to drilling parameters should be made at the rig level, the following options must be considered/studied before tripping in the hole with a percussion tool.

1. Hammer selection;
2. Air Volumes;
3. Differential Pressure / Choke Size;
4. Weight-On-Bit / RPM.
5. Stabilization & PD feature

Hammer selection can be the most complicated option to consider since there are many manufacturers and designs and the details of each hammer's operational characteristics (i.e. piston weight, frequency, actual stroke length, etc.) are not clearly documented for comparison. It has been noted in field operations that in hard formations, a hammer with a heavy piston and/or long stroke will usually out penetrate a hammer with a light piston and/or short stroke, especially in "misting" applications. Sometimes it is difficult to see a major difference in the rate of penetration in softer formations and/or when "dusting". However, in soft formations, it is also worth noting that the bit life is often extended with a hammer with a lighter piston and/or short stroke. Thus, for Terrell County, where most of the applications have medium formation strengths and can be dusted, a hammer with a higher frequency but moderate impact strength delivers the optimum rate of penetration and bit life.

The lifting power of an air drilling system is proportional to the circulating density and to the square of the velocity. Therefore, the annular velocity is the primary factor in transporting the cuttings to the surface. In the Val Verde Basin field observations over the past several years suggest that the optimum air volumes should deliver an annular velocity of *5000* feet per minute to properly clean these straight dusted holes. It is also suggested that an additional **30%** air volume (add one compressor) should be used when misting or drilling a directional hole.

Most hammer's will have a "by-pass" choke for allowing additional air to be circulated (for hole cleaning) without running the hammer over its operating parameters. The majority of air hammers suggest that *300* -- *350* psi differential pressure is best but when field operations see higher ROP's with increasing differential pressures, the tendency is to run 400 – 450psi to obtain the maximum feet per hour. Unfortunately, these high differential pressure often lead to premature piston or bit failures. In the Val Verde Basin, the optimum differential pressure has been found to range from *350* to *380* psi while dusting and therefore the choke size is currently chosen to fit this range.

Other operating parameters that affect the performance of air hammers and bits is the Weight-on-Bit (WOB) and RPM. The rule of thumb for hammer bit WOB has been 500 lbs per inch of hole diameter (i.e. 7 7/8" = 4000lbs WOB) but in the Val Verde Basin lighter WOB has proven to produce longer bit runs so typically only 2000 - 3000lbs WOB is used for 8 ¾" holes. The rotary speed of the hammer bit should be matched to the operating conditions of the hammer (i.e. frequency) and the bit design. It has been found that the optimum RPM for the medium rock formations of the Val Verde Basin is around 40 RPM. By analyzing this rotary speed for an 8 ¾" H42 bit and a hammer that was operating at approximately 1500 beats per minute, it would suggest that the piston is striking the bit each time the gage inserts have moved one full diameter (22mm or 7/8"). For harder formations and also for larger bit sizes, the rotary speed is suggested to be lowered to 20 RPM or less so that the gage insert will travel approximately half its diameter between impacts.

Although many fields in the Val Verde Basin are considered deviated areas, air hammers have proven to drill straight holes[3,4] with slick BHA's due to the very light WOB required for the bit. Without stabilizers, it is possible to drill holes that are undergage without being detected. The PD feature (Protected Diamond Gage/Heel) has added even more value to the H42 bit design because it will minimize the chance of undergage hole by acting as an early torque indicator. An example of this is, if the H42R8R3 bit drills an additional 2000 feet but 500 feet must be reamed by the following bit, then the extra rig time to ream the hole could eliminate the savings from the first bit run. The PD feature (Figure 6) will prevent this reaming situation.

New Technology

The use of Diamond Enhanced Inserts continues to grow within the drilling industry. Shaped DEI's are today used in Roller Cone Bits for abrasive formations to prevent gage wear as well as for directional and horizontal holes. Continued research and engineering development of shaped diamond enhanced inserts is expected to help improve air hammer and roller cone bit life and footage in the future. Further work is also required in anticipation of drilling harder and more abrasive formations as the search for hydrocarbons extends below abrasive volcanic and igneous rock formations.

Conclusions

1. 3rd Generation Impax Hammer Bit (H42R8R3PD) design has proven to out drill older designs by as much as 73% in the Val Verde Basin.
2. Improved Best Drilling Practices including hammer selection, air volumes, differential pressure, WOB and RPM have contributed to this large increase in total footage.
3. Use of PD feature minimizes the chance of reaming situations.
4. Use of the patented Hammer Bit Retaining System minimizes the chance of lost-in-hole situations.

References

[1] Reinsvold, C.H., Clement, J., Oliver M., Witt, C., and Crockett, J., "Diamond Enhanced Hammer Bit Reduce Cost Per Foot in the Arkoma and Appalachian Basins", SPE/IADC 17185, 1988 SPE/IADC Drilling Conference, Dallas, TX, Feb 28 – Mar 2, 1988.

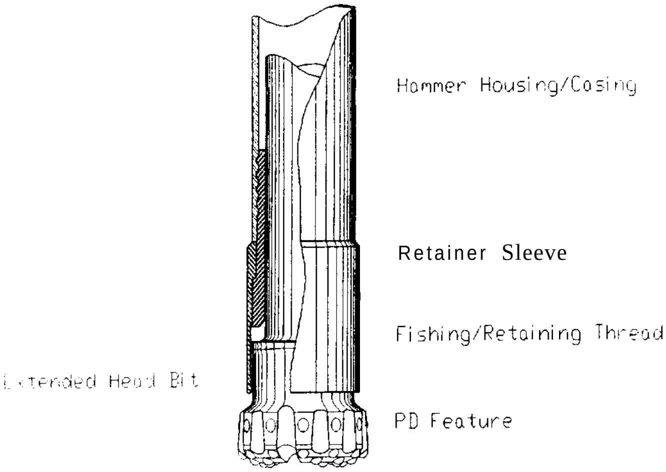


Figure 1 - Hammer Bit Retaining System

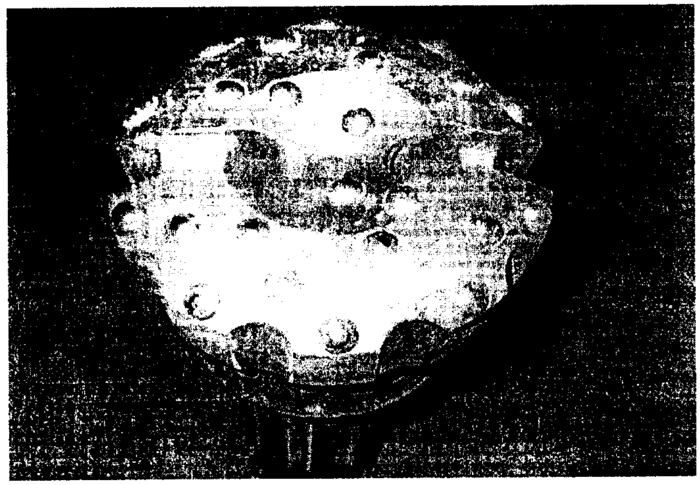


Figure 2 - 8 3/4" H45R8R2 2nd Generation Impax Bit

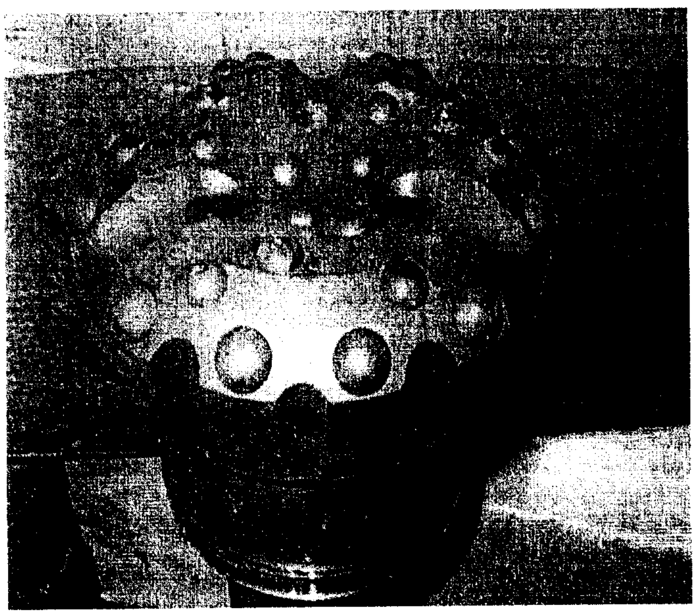
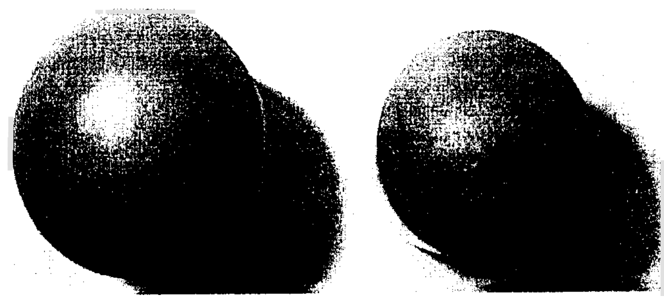


Figure 3 - 8 3/4" H42R8R3 3rd Generation Impax Bit



22mm 18mm

Figure 4 - Diamond Enhanced Inserts

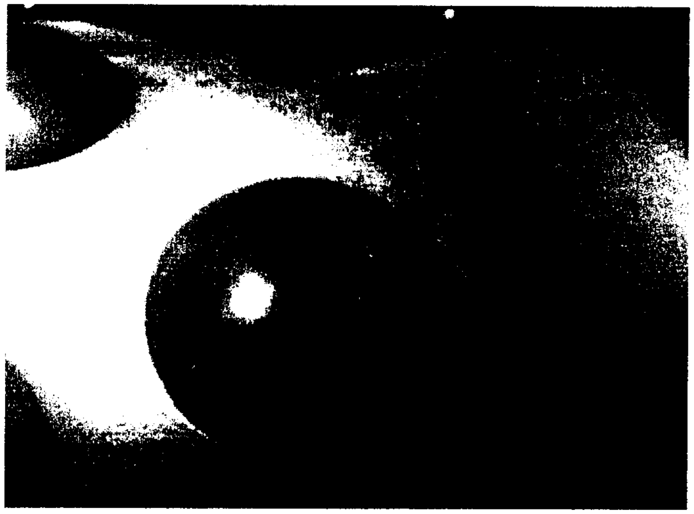


Figure 5 - New DEI Gage Wear Pattern

Figure 6 - PD Feature Prevents Reaming