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Hard Formation Underreaming for Expandable Liners

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Abstract

The use of Enlarge While Drilling (EWD) operations[1] in hard drilling applications has given operators the ability to execute slim well designs at considerable cost savings. The choice of underreaming tool for these hard drilling applications is critical to preventing drilling problems as well as enhancing drilling performance.

This paper looks at several underreaming tools used in such a drilling program and analyzes the results achieved. The drilling parameters which indicate a successful EWD operation are shown and discussed. Also, there is a brief summary of the slim well design concept and the expandable tubulars utilized.

Finally, a listing of the lessons learned from the more than 20 wells and the design modifications made to improve durability and performance of underreaming tools are stated.

Introduction

EWD tools have been used in various formations over the last decade. The implementation of a concentric underreamer to simultaneously drill and underream has provided many benefits to the operator including better directional control and improved ROP. Older type underreaming tools like bicenters (plus other winged reamer tools) and pressure actuated flip arm underreamers have been in use over the last half century with limited success depending on the application. In the past, the use of EWD tools for underreaming operations in deep oil and gas wells has been challenging. Enlarging While Drilling of hard abrasive formations has rarely been considered due to the risk and cost.

The challenge presented to Burlington Resources in late summer of 2004 was how to cost effectively develop their high temperature and high pressure Deep Bossier discovery in East Texas (Robertson County, Texas). The solution was a new ingenious slim well design which included Solid Expandable Tubulars (SET) as well as novel underreamer tools[2]. Although the concept has been mentioned in various papers in the last decade[3, 4], the successful execution in hard formations has been extremely limited.

The Bossier sands are a high compressive strength and abrasive formation in which tool failures and multiple trips in and out of the hole are common. One of the difficulties was finding a underreamer which would be able to economically and reliably enlarge the SET hole section. This was critical in order to be able run the SET, expand it and cement it successfully. Both winged reamers (eccentric tools) and different concentric reamers were tried. The hard sand formations encountered led to short runs and severe wear on several of the reaming tools. Several of the reaming tools made design changes in hope of improving durability and tool performance.

Well Design and Drilling Operations

The slim casing design has been discussed in many papers[1, 3, 4, 5] and the practical application has been done in several wells particularly in deepwater operations. The main purpose for designing these development wells using the slim casing design was to enable a larger production casing size while reducing the surface and intermediate casing sizes. A big benefit realized was the faster ROP in 9 7/8” intermediate section as compared to the standard 12 ¼” hole that was drilled in previous standard casing design wells.

A conventional or typical casing plan would have started with a larger surface casing in order to end up with the same or even a smaller production casing size. The extra cost in using larger size casings and liners is significant. In addition, the rig must be capable of handling a greater lifting load to run the various heavier tubulars demanded by such a conventional well plan[4]. While it is true the SET is a higher priced liner as compared to a standard liner of the same size, the above mentioned cost savings more than compensated for the additional cost of the SET (Figure # 1).

Once the standard 7 5/8” casing is cemented, the critical SET hole section must be drilled and underreamed. The rest of the paper will deal with this hole section and the different attempts to successfully accomplish a full gauge underreamed hole. The exploratory wells drilled in this field led to several valuable insights on how to drill and underream. The different BHA configurations tried were running the reaming tool directly above the bit as well as running a near bit six point stabilizer between the underreamer and bit. On some of the wells, the reaming tool was run in an existing pilot hole and underreaming was done as a separate run.

Once the section has been drilled and reamed, a cleanup run is made using two full gauge tandem stabilizers above the bit. This is done in order to insure the hole is proper size and the well bore is smooth with no severe doglegs (tortuosity) which would prevent the successful expansion of the SET liner. This method is recommended by the SET service company to assure a good quality hole to expand their tubulars.

Background on Reamer Tools

Several different types of underreaming tools were tested on these wells from winged reamers (bicenters or other non-concentric reamers) to concentric reamers from different suppliers. The use of a concentric tool takes advantage of a full size pilot bit as compared to a small pilot bit demanded by a winged reamer tool's pass through requirements. As a result, the concentric reamers are only cutting around 25% of the hole volume as compared to 55% in most winged reamers. This leads not only to longer bit life, but a smoother wellbore. All these factors result in less time tripping out of the hole to change BHA components and more time drilling. Faster ROP is another benefit of some of the concentric reamer tool designs. The concentric reamer cuts less formation and therefore the ROP is controlled by the bit which does most of the work and is easier to stabilize.

All of the advantages stated are of little importance if the wellbore quality and hole gauge are so poor that casing cannot be run. There is a strong tendency for winged reamer type underreamer tools to drill a spiral hole simply due to its eccentric design. This tendency is not seen with concentric tools. However, concentric tools which rely on pressure to keep their cutters activated encounter problems as the formation becomes harder or the angle of the well increases (as more weight of the BHA is being supported by the low side cutter causing the formation to push the cutter back in every time it rotates to the low side of the hole)[6]. Pressure is not sufficient to consistently overcome the force on the cutters as the tool rotates against a hard formation (Figure # 2 and Figure # 3).

The EWD® was the only mechanical (or weight activated) concentric reamer used in this well program (Figure # 4). The advantages of a balanced cutting structure seen in concentric reamers coupled with a solid steel support for the cutter blocks was made apparent early in the underreamer tool testing. The better performance of a mechanically designed underreamer versus the competing tools became more obvious in the harder formation. In addition, the EWD®'s reverse nozzles improved the ROP owing to better bottom hole cleaning at the bit face. Finally, the EWD®'s mechanical design when locked allows any slight hole irregularities to be backreamed. A winged reamer design requires weight to be applied on the bit so as to give it a point to pivot around and therefore, backreaming is not possible.

Reamer Operations and Drilling Results

A total of 22 wells had been drilled and reamed at the time of this paper. There was a significant difference in performance between the different reaming tools. For the sake of brevity, the data from all the wells to date will be presented in a table first (Table # 1), followed by a discussion of the key points shown in this data.

This data shows a significant difference in average footage achieved per tool with the concentric EWD® having by far the most tools run and footage. The average feet per tool for the EWD® increases significantly to over 680 feet per tool if you leave out the first two wells run on. These first two wells like many drilling operations involved a learning curve. Another important point is that all 7 of the non EWD® reamer runs came out with the hole severely undergauge and in all instances the hole had to be re-reamed before the SET could be run successfully.

Longer continuous runs without having to trip out of the hole were accomplished due to the EWD®'s mechanical, symmetrical design eliminating fluctuating torque. This in turn lowered or even in some cases eliminated the vibration in the BHA. The damage caused to drilling or reaming tools under extreme vibration or shock becomes not only more severe in harder formations, but the amount time that tools can survive in this type of environment is dramatically shortened. The key factor is establishing an even cutting action with the reamer cutters. A part of this process is accomplished with proper stabilization of the BHA. The other involves insuring the reamer's cutting structure is solidly supported and that there are no major or micro movements laterally (cutter movement in-and-out of the tool body).

Figure # 5 illustrates the difference in torque in the same well between the EWD® and a winged reamer. This figure is a perfect example of uneven cutting action resulting in fluctuating torque and therefore shock loading on the winged reamer cutting structure. This lead to a short run as well as a tool with no cutters left on the winged reamer blade (Figure # 6). As a result, the hole was at the gauge of the small 5 ½" pilot bit which is required for the winged reamer to pass through the intermediate casing.

Severe fluctuating torque is an immediate indication of the cutting structure not being evenly loaded and an unstable BHA which will only lead to damaged drilling tools. The PDC cutters used today suffer most often from impact failure due to the diamond inserts slamming into the formation. This breaking of the PDC insert face happens quickly in hard formation leading to more unbalance in the cutting structure and greater fluctuating torque. This cascading effect is what results in reaming tools being pulled with all the PDC diamonds gone. The sign of this is the torque reading fluctuating between a larger range in the beginning as a result of the first series of PDC inserts being lost followed by a reduction in fluctuating torque due to less cutters being available and therefore a lower overall torque being generated. Often times if the underreamer is completely worn down, then all the torque will be coming from the bit.

Stabilization of the bit and underreamer are accomplished with different BHAs depending on the application and history of tool wear. A near bit stabilizer should be used when bit life is the limiting factor in effectively completing the section. Also, at least two string stabilizers, placed one drill collar joint apart above the underreamer, should be used to keep the underreamer centered in the hole while cutting. When bit wear is not an issue the near bit stabilizer can be left out of the BHA.

Expandable Liner Pre-Running Operations

Once the hole is drilled and reamed to the required size, the hole is further verified for running the liner and expanding it by checking the hole with a dummy run BHA. The dummy BHA run is simply two stabilizers stacked right on top of each other with their size being the same as the expanding plunger which will be used to make the liner expand to the final outer diameter size. This gives a very reliable indication if the plunger or pig used to expand the liner from the bottom to the top will be able to pass without getting stuck. This dummy run will not only check hole size to a degree, but will identify hole issues like doglegs and other hole irregularities. Calipers are usually ran to get quantitative and qualitative idea of hole size; however, the dummy run BHA is the only current method used to mechanically verify the hole is ready for the expandable liner to be run.

Tool Improvements and Future Plans

The successful implementation of the slim well design and the significant cost saving associated with accomplishing it, rely heavily on utilizing reaming tools which can effectively and economically cut the formation[5, 6]. As demonstrated in the more than 20 wells drilled to date by Burlington, EnCana, ConocoPhillips, and others in the deep, high pressure and high temperature Bossier formations. These hard formations can quickly destroy conventional or standard tools of all type.

Although the performance of the mechanical EWD® was advantageous as compared to the other reamer tools tried, there were valuable lessons learned on the first few wells. This early experience guided the development of changes in the design in order to achieve greater performance plus the elimination of any potential problems. First, the standard top connection was changed to a higher torque XT-39 connection as the rest of the BHA string. Also, the cutting structure support was increased to enable applying optimum drilling parameters with the EWD® for higher ROP and longer runs (Figure # 4). These changes have resulted in longer continuous runs with faster ROP as illustrated by a 1,519 feet run with one tool at an average ROP of greater than 40 feet per hour.

Several operators plan to continue running the SET and using the EWD® to underream this section. Once the initial wells are drilled over the entire acreage, then further development will continue with in-field drilling between these initial wells. The other reamer tool companies have been asked to develop or design a tool capable of reaming these wells, but as of yet none have been made available.

Conclusions

The economic advantage of designing a slim well design has been demonstrated by Burlington in their deep Bossier drilling program with the average cost savings of over $1.2 million per well[1]. The ability to successfully run a SET depends heavily on a full gauge hole being underreamed efficiently. Through the trials of different reaming tools, Burlington and other operators have found the EWD® to be the most effective in drilling performance and therefore the best economic option.

The most important factor in successfully underreaming a hard formation is being able to maintain an even or balanced cutting action. The degree of steady drilling torque is an immediate sign of how smooth this cutting action is. The primary cause of reamer tool failures in hard formation is due to strong impact forces completely damaging the PDC cutters. The benefits of a concentric, mechanically operated tool become more and more apparent as the formation hardens and the downhole forces acting on the reamer increase.

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Nomenclature

BHA = Bottom Hole Assembly
SET = Solid Expandable Tubulars
PDC = Polycrystalline Diamond Compact
ROP= Rate of Penetration
EWD= Enlarge While Drilling
TD = Total Depth

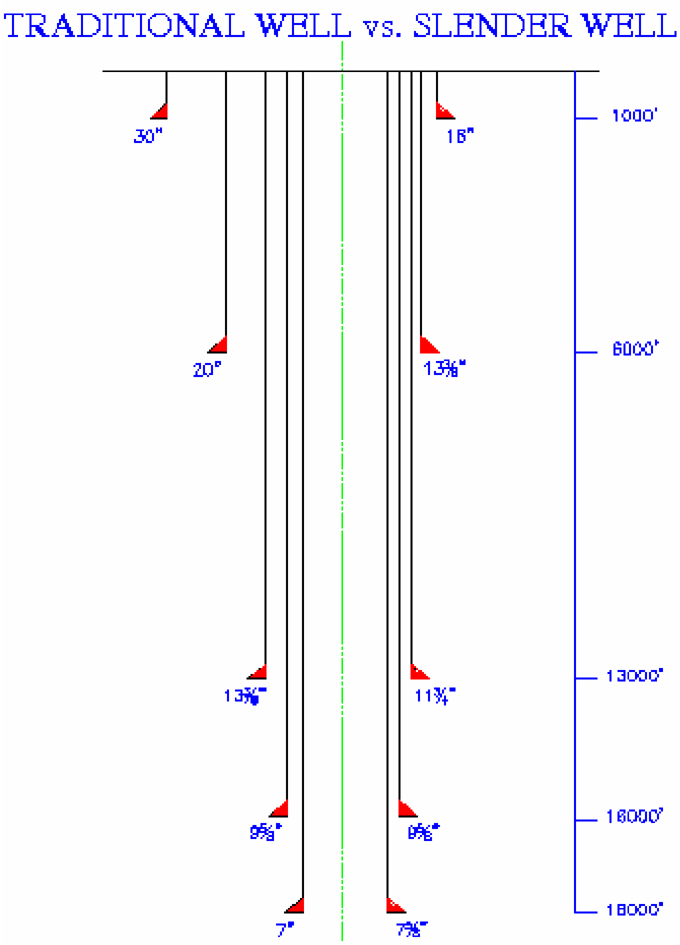
References

1. Tubbs, D., Wallace, J., "Slimming the Wellbore Design Enhances Drilling Economics in Field Development," Paper SPE 102929, Presented at the AADE 2005 National Technical Conference & Exhibition, Houston, Texas, April 5 - 7, 2005.
2. Lenamond, C., Silva, A., "Comparison of Concentric Reamer Technology to Eliminate Wellbore Threading in Deepwater Wells," Paper AADE-05-NTCE-43, Presented at the AADE 2005 National Technical Conference & Exhibition, Houston, Texas, April 5 - 7, 2005.
3. Barker, J.W., "Wellbore design with reduced clearance between casing strings," Paper SPE 37615, presented at the 1997 SPE/IADC Drilling Conference, Amsterdam, March 4 - 6, 1997.
4. Filippov, A., Mack, R., Cook, L., York, P., Ring, L., and McCoy, T.: "Expandable Tubular Solutions," SPE PaperNo.56500, presented at the 1997 SPE Annual Technical Conference and Exhibition, Houston, Texas, Oct. 3-6, 1999.
5. Sheshtawy, A., Howell, M., "Cut Costs with New BHA for Reduced Clearance Casing Programs," World Oil, December 1999, pp. 59-62.
6. Sheshtawy, A., Sheshtawy, N., "Slender Well Plan for Lower Cost and Improved Safety," Paper AADE-05-NTCE-39, Presented at the AADE 2005 National Technical Conference & Exhibition, Houston, Texas, April 5 - 7, 2005.

Tables

	Total Footage	Number of Tools	Feet per Tool
EWD®	10,136	20	**506.8**
Winged Reamer	480	3	**160.0**
Concentric Reamer #1	245	2	**122.5**
Concentric Reamer #2	137	2	**68.5**

Reamer Drilling Results
Table # 1

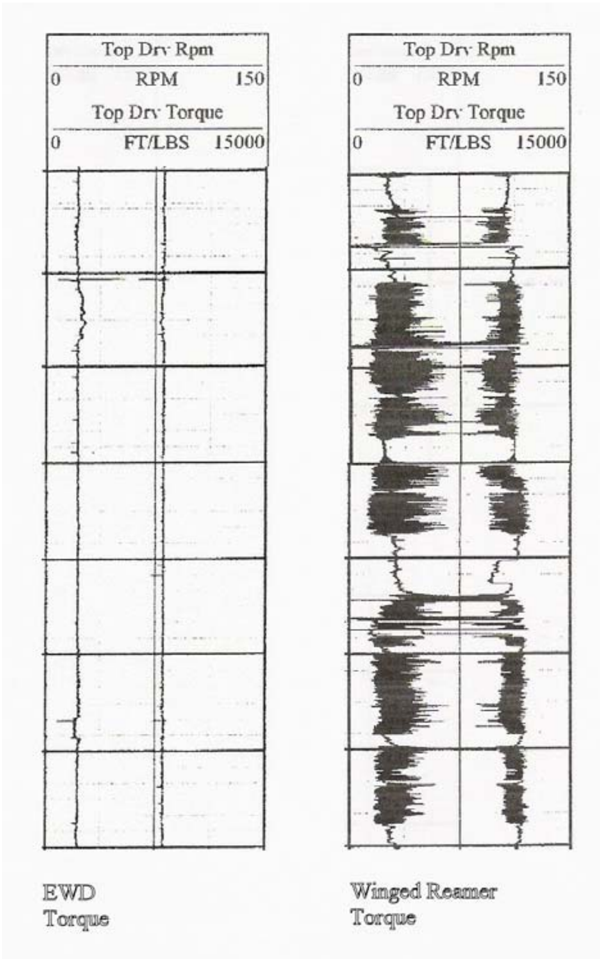


Slim or Slender Well Plan
Figure # 1

Concentric Reamer # 1
Figure # 2

Concentric Reamer # 2
Figure # 3

Concentric Reamer # 3
Figure # 4



Drilling Torque
Figure # 5

Winged Reamer
Figure # 6