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Application of Steerable Hole Enlargement Technology in Complex 3D Directional Wells, Offshore East Malaysia

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Abstract

The paper describes application of steerable, hole-enlargement technology in a complex 3D directional application. Following repeated failure of Bi-Center bit technology to meet demanding requirements in a number of offshore East Malaysia wells, the Near Bit Reamer (NBR) was used in a variety of BHA configurations to drill six wells for Shell Malaysia-EP. Cuttings Bed Impeller (CBI) tools were also included in the drill string to facilitate hole cleaning and maintain hole quality. The resultant hole profiles enabled good cement bonds to be achieved for the 7⅝" "SMART" liners, and excellent gravel pack results for the 4½" production liners.

In addition to achieving hole enlargement in a single run, compared to multiple-trips for reaming, use of the NBR and CBI tools provided a fast, clean hole that allowed good casing runs. To date, the NBR tool has been utilized on more than 11 highly deviated wells with no stuck BHA occurrences, where prior experience without the NBR/CBI tools produced at least one stuck BHA per well.

Furthermore, efficient hole enlargement operations in this application allows for SMART completion options, with 7⅝" liner instead of 7" liner for multiple completions that allow selective production, an option that was not possible prior to this.

Introduction

In these offshore South Furious field wells, the objective was to drill out 9⅝" casing shoe track and the deviated hole to section TD in a single bit run. The hole was drilled using an 8½" bit and was concurrently opened up to 9⅞" using the NBR.

The well trajectory had a 3D profile, and exhibited controlled dogleg severity ranging from 3 to 8° per 100 feet while employing a 1.5° bent sub and a rotational speed of 100 RPM. An additional requirement was for the hole profile to be of minimum spiral form to enable optimal hole cleaning and wire-line and/or coring conditions.

A secondary benefit from the NBR and low angle bent sub was the ability to rotate the drill-string when required.

To assist in hole cleaning, a number of CBI's were incorporated in the drill string at 500 foot intervals throughout the tangent section. The CBI tools provided for excellent agitation of the cuttings on the lower side of the hole. This eliminated any issues with ECD, and allowed liners to be run to TD smoothly, with a corresponding good quality cement bond as a result.

Background

Bi-Center technology was applied to test whether a Bi-Center bit will drill faster and better than conventional bit and also for future study of drilling an oversized hole below the 7" liner. The bit suffered balling problems and penetration rates dropped to less than 5 ft/hr.

In a second test, a Bi-Center was required to drill 14½" by 17½" hole to set the 13⅜" casing below the 16" liner. However, in this instance, tool-face could not be controlled, which presents a big collision risk in platform drilling. In addition, the reamer blade was completely wiped out when encountering stringers, leading to down-hole tool failure.

The 14½" by 17½" Bi-Center bit lasted only 500 feet while sliding without hanging up, and once the reamer blade is worn it is virtually impossible to slide.

With Bi-Center bits, the motor bend was set very high (> 2° bend) in order to achieve even a 2° per 100 ft dogleg. Due to the ratty formation, the 9⅝" motor was only good for one run.

It proved virtually impossible to underream or enlarge the spiraled Bi-Centered hole.

In a third attempt to use a Bi-Benter bit on the plastic shale formation, the bit suffered a complete halt in ROP.

NBR vs. Conventional Hole Enlargement

There are a number of advantages of using the NBR over other hole enlargement methods such as Bi-Center bits and PDC Underreamer. The NBR can be used successfully inside casing when drilling the cement plugs, where conventional means normally cannot. While PDC Underreamers have flow restrictions, and typically produce a high-pressure drop of more than 500psi, the NBR by contrast, has no flow restrictions, and very few moving parts.

By nature of its design, the NBR tool can be used to ream a pre-drilled pilot section and has a tendency to perform well in directional applications where Bi-Center bits can induce damaging vibrations and spiraled well-bores.

The NBR can be described as a modified underreamer capable of drilling out the casing shoe, before opening up and drilling an oversized hole while drilling ahead below the casing. (Figure 1) It is fully forced balanced on rotary steerable BHA's, has no pressure loss for use in high flow rate applications, and is very simple in design and easy to operate.

In operation the NBR is similar to a three bladed near bit stabilizer. The tool is activated by hydraulic force to open the three cutter arms, which move radially outward when there is a pressure drop below the tool. The pressure acting on the flanges forces the arms open, springs are used to retract the pistons to their original dormant position.
There is no locking mechanism to jam or malfunction, and shear pins allow the NBR to be run dormant or closed, while drilling out of the casing shoe.

The tool is versatile in its design and can be used in a number of BHA configurations, including rotary BHA, rotary steerable BHA and steerable PDM BHA.

In addition the NBR can be used as a full gauge stabilizer further up the BHA, providing enhanced centralization for good quality well logs. Three contact points on the NBR create a centric drilling action that holds the BHA in the normal center of the hole. This centralization reduces BHA vibration, fatigue and LWD failures.

Table 1 summarizes NBR hole enlarging capabilities by tool size.

In the subject wells, the NBR's were run in conjunction with a Sperry Sun drill motor with a short bearing pack, which assisted in generating the required dog leg response with minimal tortuosity of the well path.

In two wells, NBR tools were run in tandem between the motor and rock bit, enlarging the hole to 9⅞" after coring operations, and continuing to section TD.

To date the NBR tool has been utilized on more than 11 highly deviated wells with no stuck BHA occurrences, where prior experience without the NBR/CBI tools produced at least one stuck BHA per well.

Cuttings Bed Impeller

The Cuttings Bed Impeller (CBI) is a simple, one-piece string component designed for use in applications where hole cleaning is critical. The CBI features chevron-shaped interruptions that agitate cuttings to prevent build up and facilitate removal. (Figure 2) The action results in reduced drill string torque and reduces the likelihood of stuck pipe.

Typical CBI applications include where surface equipment limitations result in poor hydraulics, and where cuttings bed build-up causes difficulty in sliding and hole cleaning.

CBI application criteria also include high angle wells such as the subject wells, in which doglegs ranged from 3 to 8° per 100 feet, with tangent sections of 3,000 feet or more.

Use of the CBI produces a number of benefits that include reduced drill string torque, shorter trip times (no pumping out), and less wear on drill string, top drive and casing. In the offshore East Malaysia wells, a primary benefit was the elimination of stuck pipe incidents, with corresponding improvement in hole quality.

Hole Enlargement While Drilling Operations

Subject well trajectories had 3D profiles, and exhibited controlled dogleg severity ranging from 3 to 8° per 100 feet. The objective was to drill out 9⅝" casing shoe track and the deviated hole to section TD in a single bit/BHA run.

Enlarging the hole to 9⅞" out of 8½2" hole while drilling allows for 7⅝" rather than 7" liner to be run. This in turn provides the option of employing a SMART completion that allows selective production from various zones.

An additional requirement was for the hole profile to be of minimum spiral form to enable optimal hole cleaning and wire-line and/or coring conditions. Therefore, CBI tools were positioned at 500 foot intervals through the tangent section to facilitate cuttings removal.

The hole was drilled using an 8½" bit and NBR on a Sperry Sun drill motor with a 1.5° bent sub and a short bearing pack, which assisted in generating the required dog leg response with minimal tortuosity of the well path. Rotational speed of 100 RPM was maintained.

This assembly was used to drill the section while achieving doglegs ranging from 3 to 8° per 100 ft to turn the complex 3D well-path. Using the NBR enabled the hole to be drilled and simultaneously opened up to 9⅞".

Use of the CBI tools prevented cuttings build up by agitating cuttings on the low side of the hole, and provided excellent cuttings removal.

In two wells, NBR tools were run in tandem between the motor and rock bit, enlarging the hole to 9⅞" after coring operations, and continuing to section TD.

Requirements: 8½" X 9⅞" Hole Below 9⅝" Casing

In general, hole enlargement was desired for the subsequent 7⅝" liner run, 4½" production tubing, better cementing and gravel packing. The assembly had to be capable of drilling cement, float and shoe of the 9⅝" casing, and the 8½" by 9⅞" hole section in one bit/BHA run. The well-path for these sections were 2D or 3D profile.

Another requirement of the assembly was to yield consistent dogleg of 3° to 6° per 100 foot with a low bent setting of 1.5° where string rotation of 100 RPM is possible.

An additional specific requirement was to create a non-spiral hole as compared to Bi-Centered bit run. The 8½" hole must be able to be opened to 9⅞" after logging or coring.

Performance Summary

Table 2 summarizes NBR performance in the East Malaysia wells, in which NBR tools were used in both directional work and wiper trips prior to running lining. As shown in Figure 3, the NBR800 was run on a Sperrydrill motor to drill cement, float, shoe and TD the 8½" by 9⅞" hole in one trip run. This was achieved while simultaneously yielding a good dogleg response of 8° per 100 foot using a standard bent setting of 1.5° which enabled the BHA to rotate at normal surface RPM.

The short bearing pack of the 7" and the 6¾" SperryDrill motors helped to generate the dog leg response required. In addition, tool-face management was excellent and was as good as any rock bit run.. The average ROP was around 75 ft/hr.

In two wells, tandem NBR800 tools were run between the motor and the rock bit, (Figure 4) and proved effective for opening the hole toward the end of the coring point, and continuing directional work in the enlarged hole to TD.

Caliper logs confirmed that the hole size was 9⅞" or slightly bigger following these tandem NBR runs.

Benefits Realized

One Run vs. Reaming In the subject wells offshore East Malaysia, all directional objectives were met. In addition, hole enlargement was achieved in a single bit/BHA run, compared to multiple runs required for reaming operations.

Hole Quality Use of the NBR in combination with the CBI tools produced a smooth, clean hole with minimal hole spiraling. The advantages of a quality hole include efficient drilling operations and casing runs, with the attendant implications for significant cost reductions.

Increased Completion Options The ability to enlarge the hole while drilling allows for a larger liner size to be run, which affords new completion options, including multiple zone completions for selective production. SMART Well Completions offer oil and gas producers a systems approach for completing a well to provide active management of the reservoir. With the ability to monitor and control flow from or injection into multiple zones within real-time, producers can reconfigure a well's architecture at will and acquire real-time data without well intervention.

Conclusions

The NBR tool is a unique enlarge-while-drilling tool capable of drilling out the casing shoe before opening up and drilling an oversized hole below the casing. As evidenced in these offshore East Malaysia wells, the NBR can be used in a number of BHA configurations, including rotary BHA, rotary steerable, and steerable PDM BHA's.

There are a number of advantages of using the NBR over other hole enlargement methods such as Bi-Center bits and underreamers. The NBR can be used inside casing when drilling the cement plugs, can be used to ream a pre-drilled pilot section and, as shown, performs well in directional applications where bi-center bits can induce damaging vibrations and spiraled well-bores.

Use of the NBR to provide hole enlargement while drilling increases completion options. The most economical multilateral completions provide isolation of single or multiple open hole lateral groups to lateral liners that are sealed and mechanically connected to the main well-bore. With use of NBR hole enlargement while drilling, such SMART completions are now possible in complex offshore directional wells like those in East Malaysia and Gulf of Mexico.

Use of the CBI's also offers benefits that include reduced drill string torque and less wear on drill string, top drive and casing. In the offshore East Malaysia wells, a primary benefit was the elimination of stuck pipe incidents, with corresponding improvement in hole quality.

Because of the advantages of being able to run casing to TD with no stuck pipe incidents and to run SMART completions, use of the NBR/CBI tools for hole enlargement is anticipated for use in future wells by Shell Malaysia.

Acknowledgments

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Table 1. Near Bit Reamer Specifications

NBR Type	NBR400	NBR600	NBR800	NBR1000	NBR1200	NBR1400	NBR1700
Opening Range	4¾" to 5¼"	6" to 7"	8-1/2" to 9-7/8"	10-5/8" to 12-1/4"	12-1/4" to 14"	14-3/4" to 17"	17" to 20"
Makeup Length	28"	35"	36"	43"	44"	55"	60"
Body Diam.	4-5/8"	5-7/8"	8-3/8"	10-1/2"	12-1/8"	14-5/8"	16-7/8"
Fluid Bypass (%)	17%	21%	24%	25%	27%	32%	37%

Table 2. Summary of Hole Enlargement while Drilling with NBR

Well	BHA#	OD (in)	MD In (ft)	MD Out (ft)	Ftg(ft)	Comments
SF-308 (3C)	8	8.5 x 9.875	4730	5720	990	NBR800 + 7" Sperrydrill directional work 6°/100', 8-1/2" x 9-7/8", one run TD.
SF-308 (3C)	9	8.5 x 9.875	4730	5720	n/a	NBR800 + Rotary BHA Wiper Trip Run / Dress Cement.
SF-303 (1B)	12	8.5 x 9.875	3139	4481	1342	NBR800 + 7" Sperrydrill, hole-opening 8-1/2" to 9-7/8" hole TD.
SF-303 (1B)	13	8.5 x 9.875	3139	4481	1342	**Tandem NBR800** + 7" Sperrydrill, hole-opening 8-1/2" to 9-7/8" hole TD
SF-307	3	8.5 x 9.875	2772	3500	728	NBR800 + 7" Sperrydrill directional work, 8-1/2" x 9-7/8", one run TD.
SF-307	4	8.5 x 9.875	2772	3500	n/a	NBR800 + Rotary BHA Wiper Trip Run prior to 7-5/8" liner run TD.
SF-301	7	8.5 x 9.875	3852	4750	898	NBR800 + 7" Sperrydrill directional work, 8-1/2" x 9-7/8", one run TD
SF-301	8	8.5 x 9.875	3852	4750	n/a	NBR800 + 7" Sperrydrill, BHA Wiper Trip Run prior to 7-5/8" liner run TD.
SF-305	5	8.5 x 9.875	3238	3940	702	**Tandem NBR800** + 7" Sperrydrill, Hole opening to coring point followed by directional work to TD.
SJ-708B-G3	15	8.5 x 9.875	2110	4594	2484	NBR800 + 6-3/4" Sperrydrill directional work 8°/100', 8-1/2" x 9-7/8", one run TD

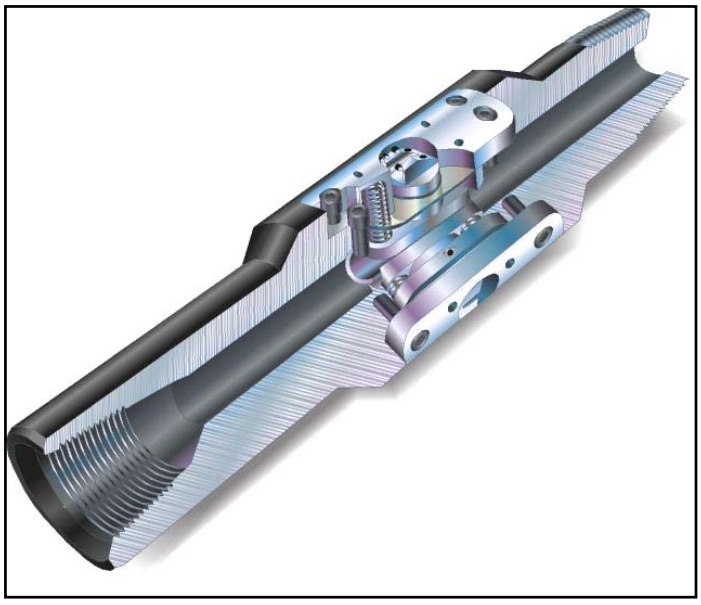

Fig. 1 Near Bit Reamer

Fig. 2 Cuttings Bed Impeller

Fig. 3 NBR 800 with 6-3/4" SperryDrill Steerable BHA

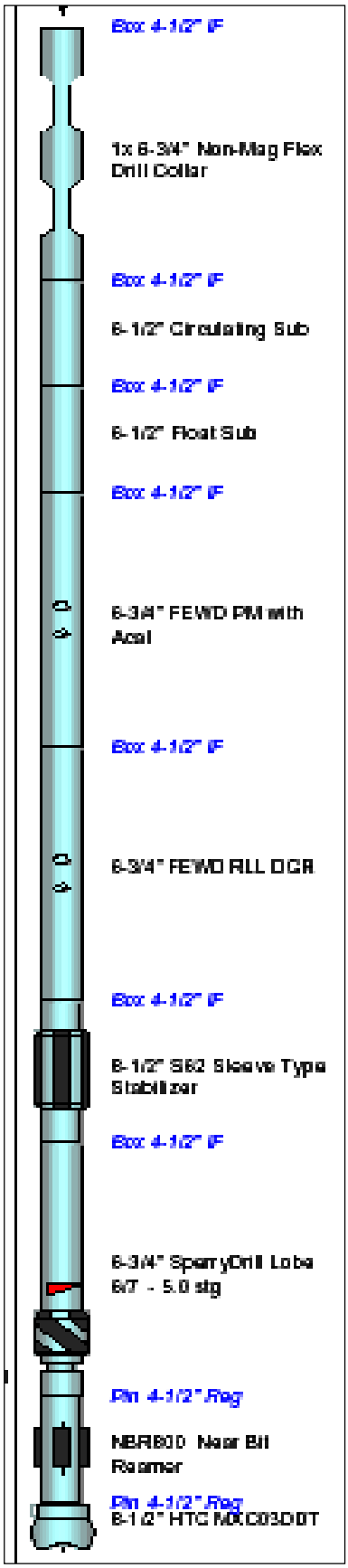

Fig. 4 Tandem NBR 800 with 7" SperryDrill Steerable BHA