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First Commercial Single-Diameter 8 x 9-5/8 in. Solid Expandable Openhole Clad Eliminates Tapering and Isolates Problem Section

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Abstract

The solid expandable tubular system brought about a significant step change in downhole architecture by instituting a technology that reduces wellbore tapering and conserves precious hole size. The single-diameter solid expandable system takes that technology to another level by eliminating the tapering effect and preserving hole size. Although the idea of the single-diameter approach has been in development for years, the concept became a reality with the installation of an openhole cladding system in the Middle East.

An operator used an 8 x 9-5/8 in. single-diameter openhole clad to isolate a troublesome shale section between ~1,500 and 1,650 ft (~456 and 503m) in a large field in the north of Oman. Previous attempts to mitigate this area with cement-reinforced slotted expandables proved unreliable. Setting regular casing in this section would compromise hole size, hinder well economics, and reduce production. The single-diameter solid expandable system provided a post-expansion inside diameter (ID) of 8.60 in. This pass-through retained an ID large enough to run the same 8-1/2 in. BHA as previously used for subsequent drilling. After placement and expansion of the single-diameter openhole clad, an 8-1/2 in. BHA was deployed to further well construction operations with adequate hole size.

This paper will describe the first installation, including evaluation and operational considerations as well as the results affirming the technology's ability to isolate problem areas without sacrificing hole size. In addition, the paper will discuss the development of the technology and explain the potential to mitigate a variety of problems and conditions.

Drilling Objectives

Wells in this field face a consistently troubling formation. The operator of this project needed to isolate the problem section, but could not afford to lose the critical ID it needed to run the tools and technology that would move the drilling program forward. Initial attempts to use cement reinforced slotted expandables proved unreliable. The objectives as confronted required a two-fold solution—isolate the problem and maximize ID.

Geological Challenges

Reservoir facies in this field are in shallow-shelf carbonates of the Middle Cretaceous Mishrif and Mauddud formations. Interparticle porosity formed in the Mishrif as sand aprons of lithoclast and skeletal grainstones surrounding fault-block islands, and less commonly in the Mauddud as biostromes of rudist packstones. Moldic porosity after fine rudist debris is more common than interparticle porosity and occurs in thicker stratigraphic units, interpreted to have formed locally in meteoric-water lenses of islands, and regionally during subaerial exposure associated with sea level lows.[1] These types of conditions exemplify an exceptionally complex geology interspersed with multiple small oil deposits, each with unique geological structures and each requiring a new approach.[2]

Operational Considerations

The drilling environment consisted mainly of sandstone with multiple interbedded shale sections. One particular section, the deepest of the interbedded shale, tended to swell and was very reactive to water, which can lead to the drillstring becoming stuck when water is passed by. To mitigate the potential for swelling, this section was drilled with inhibited water. The ideal solution to preventing swelling would consist of drilling with oil-based mud, but this approach ran the risk of contaminating shallow aquifers.

To compound the challenge, a carbonate formation below this section is prone to losses. If the troublesome shale section and the formation below were drilled together and a loss zone was encountered, the well could fill with water. This brackish water would cause severe reaction in the shale section and could collapse the hole. The section needed to be isolated but setting conventional casing would reduce the hole size and jeopardize the well economics. In the past, curing losses in the carbonate formation were time consuming and encountering another fault would require abandoning the well starting over.

The wells in this project are the soundest economically with an 8-1/2 in. hole followed by 6-1/4 in. hole into the reservoir. Scaling up the casing design to set a shoe below the troublesome shale would hinder economic viability. These factors led the operator to select Enventure's MonoSET® openhole clad (OHC) to isolate the shale without reducing the wellbore ID.

Installing a Solution

The drilling plan landed 9-5/8 in. casing at ~1,280 ft (390m) and cemented it in place back to surface. A bottomhole assembly (BHA) with a 9-1/2 in. bi-center bit drilled to a TD of ~1,660 ft (~505m) and 43° angle. Four logging runs, using four- and six-arm caliper tools, identified two tight spots. Removal of the tight spots was accomplished with a 9-1/2 in. PDC reamer and a 12-1/4 in. roller-cone reamer. The operator took extra care to facilitate proper hole size and optimum wellbore conditions prior to running the single-diameter system. This systematic precaution helped ensure a smooth installation and an uncomplicated application.

The 8 x 9-5/8 in. OHC was run to a depth of ~1,650 ft (~503m) in three hours (Figure 1). This OHC is a single-diameter solid expandable tubular system designed to maintain the hole size of the previous casing string. In contrast to a conventional solid expandable system that reduces the tapering effect, the single-diameter system eliminates tapering.

Using a hydraulic-mechanical expansion assembly, expansion was initiated with 3,000 psi. The 150-foot (47m) OHC was expanded per plan with all parameters in the expected range. An 8-1/2 in. drilling BHA was picked up and run through the expanded liner, which confirmed the expanded ID and the placement of the liner were both correct. After an 8-1/2 in. openhole section was drilled to 2,641 ft (805m), a 7 in. liner run through the OHC and cemented back to the surface. The OHC stabilized the trouble section, facilitating an efficient wellbore construction operation without compromising hole size. The operator remained on well design and drilled a 6-1/8 in. open hole to ~4,600 ft (~1,400m) as planned.

The successful installation of this first single-diameter solution resulted in the application of a second OHC by the same operator in a different well. The subsequent application took place in similar conditions and parameters. An 8 x 9-5/8 in. MonoSET OHC a~141 ft (~43m) in length covered the trouble zones and enabled the 7-inch casing to be run to the planned depth and cemented in place. Both OHC systems kept the drilling program and the original well economics intact and on target.

Developing the Single-Diameter Technology

The path to actualizing the single-diameter system took a circuitous route that included amended theoretical approaches (ex. one-trip system vs. two-trip system), numerous design iterations of tool components and subsystems, and several field-appraisal tests. An intentional focus on developing the system spanned a decade that ran parallel with the maturation of conventional solid expandable tubulars. The evolving technology, the broadening application spectrum, and the commercial deployment of the OHC in the Middle East illustrate the results of a successful strategy to provide the enabling tools and processes to "lower lifting cost and maximize recovery".

The single-diameter design concept itself was closely controlled and incorporated multi-disciplinary processes with a team that included drilling experts, engineers, designers, and end users. To develop a reliable tool for a myriad of conditions and applications, modular components proved to be the most practical plan for construction as it provided easier customization for specific applications, simplicity in overall design, and quick assembly of tools. The design team was able to leverage a sound foundation of solid expandable tubular knowledge that included an advanced understanding of pipe metallurgy, properties and the effects of stresses and strains endured during the expansion process.

Proving the Concept

The proof-of–concept, single-diameter well was completed in South Texas by Shell Exploration and Production Company (SEPCO) in July 2002. Although this project provided a multitude of technical learnings and the well was commercially completed, the actual number of trips required to construct the single-diameter sections along with difficulties in zonal isolation, made this system configuration impractical for broad-based field use in that oilfield market. However, the basic principles to construct a single-diameter well were proven.[3]

From this proof-of-concept well a more refined perception and base operational overview emerged that identified design elements that needed refining. The result was a multi-functional tool that would integrate all sub-systems and assure self-contained contingencies. This direction represented a marked divergence from any conventional solid expandable tubular tool configurations or design. A tool string prototype was manufactured and tested in a live well in late 2004.

Continued refinements and enhancements led to a field appraisal test (FAT) in 2007. For the FAT, the string tested consisted of six different tools each subjected to a vigorous testing program. Each tool was placed in a right-hand torque test to 10K ft-lbs, the maximum torque loading for the casing connections. Testing to this torque capacity, which exceeds the allowable torque for the liner, ensured that the tools could be rotated to wash down in the hole while running. The tool string was tested in the horizontal position with sand-laden fluid for flow testing and fluid cutting. In addition to horizontal, it was also run in the vertical position in oil- and water-based mud.

Following successful surface testing of the tools, the downhole portion of the FAT was initiated. As part of the construction of a dedicated test well, Enventure was able to drill deeper than the prescribed well requirements and install any number of liners as part of the test program. The test included the placement of three consecutive liners each with the same final ID of 10.4 inches. Each liner was installed using a slightly different tool configuration which emphasized the modularity of the system. The first liner was installed and included the expansion of a larger "bell" section at the bottom to act as a receptacle for the second liner. The second and third liners did not include the bell section. This required the overlap section in the second liner to be expanded along with the third liner. In all, a total of approximately 1,750 ft of single-diameter liners were installed in a hole that built to a final angle of ~55°.

The FAT provided the environment to affirm system performance and establish real results. The objective to simulate field parameters, such as high-angle bending forces, an oil-based mud environment, while confirming the functionality of the tools and the ability to cement through the single-diameter tools were exceeded by the test.[4]

The FAT also indicated that although it was possible to install single-diameter liners in a single trip, the complexity of the operation would need to be reduced for it to become a common practice. The natural progression is to break the process down into more simple pieces like the single-diameter OHC and shoe extension. Eventually, through experience and refinement, the smaller pieces will come back together in the construction of a true single diameter well

State of the Technology

The current operating parameters of the single-diameter openhole clad system provide an 8-1/2 in. pass through below the 9-5/8 in. casing. This system can be expanded against the formation, eliminating the need for cementing and the need to tie-back into base casing. The preservation of hole size can be the length of a single joint to or over 1,000 ft. The running sequence of the single-diameter openhole clad system is similar to conventional solid expandable tubular systems (Figure 2).

1. Drill thru problem zone
2. Run liner and inner-string
3. Expand liner across problem zone
    - Activate anchor
    - Expand lower seals
    - Initiate mechanical expansion
4. Recover tools and operational pipe
5. Drill ahead

Identifying the Potential

The use of single-diameter expandable casing technology has the field-proven potential of significantly reducing a project's drilling and completion cost structure. These savings are realized by reducing drilling risk and resultant trouble time by successively isolating problem lithology and/or under-pressured zones while preserving a single-diameter wellbore. Reductions, in turn, result in zero compromise of the completion objectives and afford much greater completion flexibility and potentially lower the life of well costs with improved completion design and required interventions. Gulf of Mexico operators, which often encounter severe lost circulation zones at shallow depths, are watching the technology development in hopes of expanding long drilling liners to isolate these under-pressured zones and then later case off the expanded liner and problem zones. Other operators see the great potential of installing several uphole single-diameter drilling liners to allow a fullbore completion at total depth (TD).

The technology also has the proven, simulated and engineered potential of significantly increasing the lateral reach of many extended reach wellbores.[5] Successive installation of expandable, single-diameter wellbores is possible, which primarily reduces the friction/drag forces that can limit lateral reach, again, while preserving a single-diameter wellbore as deep as required. In addition, this application affords higher weight-on-bit at comparable depths versus conventional drilling technology. This extended lateral reach results in increased reservoir contact that can often result in increased production per well.

Extended-reach laterals can be cased with successive liners that preserve ID. Using shorter lengths of casing that maintain a constant ID prevents friction and drag increases. A study done for a major North Sea operator showed that single-diameter systems could extend the current ERD envelop up to 50%.[6] The study concluded that added reach achieved by reduced friction could lower well count, raise well production, increase reservoir contact, increase reserve access, improve capital efficiency and lower field development costs. Proven drilling performance and additional cost studies indicate that expenditures reflected in the same North Sea study area could be reduced 30 to 50% of the current drilling cost with the application of solid expandable tubulars and constant-diameter technology.

More production from fewer wells can ultimately lower required field well counts with an improved drilling cost structure profile. In select offshore applications, this technology can in turn result in lower platform installation requirements without reserve reductions or potentially increased reserves by tapping flank or step-out reserves. In many subsea applications, the technology can result in lower subsea templates, flowlines, pipelines and production center requirements. The technology also offers enhanced development flexibility with minimum economics by allowing the deferral of high capital cost outlays with improved development phasing. In subsea applications that include seabed geohazards, such as escarpments or Arctic iceberg risks, the reduced subsea infrastructure requirements further mitigates project risk and improves field economic returns.

In modeled worldwide offshore and subsea developments, the system greatly reduced observed and/or forecast drilling risks and trouble time. The modeling indicated that the prudent application of successive single-diameter expanded liners has proven to increase lateral reach potential by 25 to 50% and in select applications, these results exceed the current industry lateral reach record by over 35%.

In formations such as hard rock, the single-diameter system could be used in an openhole configuration to clad over problematic formations in an otherwise stable section. Wellbore diameter is maintained and the operator forgoes the need and cost to cover an entire zone. Another obvious benefit of this technology suite is its ability to facilitate a shoe extension. Multiple casing points can be made up or initially attained without losing hole size.

Conclusion

The successful installation of the previously discussed single-diameter systems strategically mitigated trouble zones in the formation by isolating targeted sections of the wellbore without anchoring back into the previous casing. Proving the validity of the equipment, the process, and the potential opens the possibility of diverse applications with far-reaching benefits. As with conventional solid expandable tubulars, the more the technology is utilized the greater the benefits realized. These benefits include decreasing drilling cost structure and/or reducing drilling risk and trouble time, improving field development economics, accessing greater reserves, increasing production per wellbore, and potentially creating a smaller field development footprint These systems no doubt will play a significant role in the current climate of accessing reserves that not only affect the bottom line but save time and resources as well.

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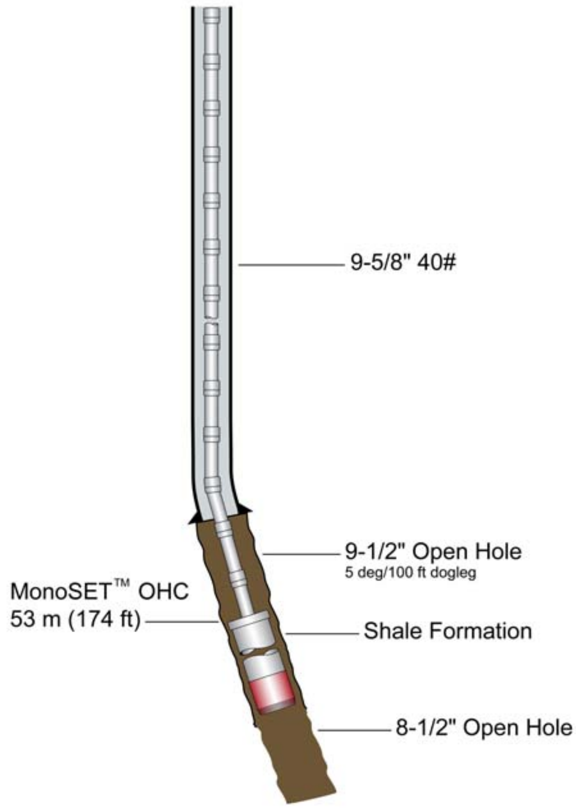

Figure 1 – Single-diameter openhole clad isolates troublesome shale section.

Figure 2 – Running sequence for the single-diameter openhole clad system.