Optimizing Drilling Operations with Solid Expandable Tubulars

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Abstract

Deep water and extensive lengths are no longer an anomaly for drilling conditions but a matter of course. Increasing vertical depth and lateral reach requires adequate hole size to attain the desired objectives of the wellbore. With over 1,000 installations since inception in the late 1990s, solid expandable systems have proven their worth in maintaining and retaining hole size to address both physical limitations and economic feasibility, especially in deepwater operations.

Incorporating and planning solid expandable systems into wellbore construction as a design element rather than a contingency plan has averted numerous problems identified from offset data or real-time challenges during the drilling process. The broadening application realm for this enabling technology includes multiple expandable systems in a single wellbore, expansion through milled windows, use in high-pressure/high-temperature conditions, and facilitating extended-reach objectives.

An in-fill drilling campaign in two West African offshore fields led an operator to install solid expandable systems through windows opened in existing casing. The expandable systems gave the operator enough hole diameter to install the necessary electric submersible pumps without having to mill existing casing or find recovery platform slots.

This paper will discuss innovative and enabling applications of solid expandable tubulars in the West African theater of operations. In addition, this paper will describe how solid expandable tubulars have helped operators successfully attain drilling objectives even in deepwater and extreme environments.
Introduction

The increasing demand for oil and gas has pushed the energy industry to re-examine and re-evaluate processes and equipment to tap potential zones and probable resources, especially in deepwater environments. Methodology, procedures and technology have had to evolve to supply the necessary tools to practically and profitably access these reserves. Solid expandable tubulars have proven to be an enabling technology that provide a substantial value proposition to field development that champions a slimmer well profile while still reaching TD with adequate hole size.

Although solid expandable tubular contingency strings have been successfully used to mitigate and manage downhole wellbore problems for years, the current shift in deepwater operations is to plan these strings into the basis of design to preserve hole size. Up-front planning of solid expandable liners allows running more casing strings to reach greater depths and provides a larger hole size for reduced equivalent circulating densities and improved logging success. As offshore well depths continue to increase, the ability to run additional casing strings enables operators to reach greater target depths and unlock more reserves. The following case histories exemplify the advantages and benefits garnered from solid expandable system application, especially in the challenging environment indicative of deepwater operations.

Case History #1 – Practical Re-entry

First Well – The requirement for difficult and hazardous casing milling operations necessitated consideration of a new approach to well re-entry programs in mature fields. The conundrum consisted of how best to wage an in-fill drilling campaign reliably, efficiently, and economically.

The in-fill drilling campaign in the Zatchi and Loango fields in West Africa necessitated a more economical and practical approach to reduce drilling time and maximize existing assets.¹ Prior to initiating the plan, analysis on available alternatives to laborious retrieving and milling operations defined the following two options:

- New drills with slot recovery
- Re-entry with solid expandable tubulars
The first option required further studies to use the slot-recovery deflecting tool. This process also appeared more expensive than the solid expandable tubulars and would require additional time to get the wells back on production.

The operator opened a window on the 9-5/8 in. casing and enlarged the hole to 9-7/8 in. with a steerable assembly and 800m (~2,625 ft) of 7-5/8 x 9-5/8 in. solid expandable casing was successfully run and installed (Figure 1). The solid expandable tubulars were deployed to the casing point and cement was pumped. During the expansion phase, the casing parted at 513m (~1,680 ft). A preliminary analysis confirmed that, in the attempt to reach the bottom, the casing was reciprocated several times to pass through a tight spot at 965m (~3,170 ft). This reciprocation caused significant wear in the connection at the low side of 9-5/8 in. window and led to the expandable sleeve breaking and the connection becoming loose. Consequently, the threads separated during expansion.

![Figure 1 - 9-5/8 in. sidetrack with solid expandable tubular system.](image-url)
The window was re-dressed with a flat and watermelon mill assembly. One of the most important factors affecting the successful implementation of solid expandable tubulars through a milled casing window is the physical characteristics of the window itself. Three trips ensured good window quality and reaming trips cleaned the hole to an acceptable geometry. Well tortuosity was minimized in the design of the second hole, which resulted in minimal pipe reciprocation in the second attempt.

The operator spent 2.4 days to run and successfully expand the solid tubulars compared to a planned eight days that was estimated for a trouble-free 9-5/8 in. milling operations. Benefits realized from the solid expandable application included:

- Better weight transfer
- Lower torque and drag
- Higher ROP
- Larger ID for future work
- Lower risk of buckling with 5 in. drillpipe
- Improved hydraulics
- Lower pump pressures
- Less hole to drill

**Second Well** – The results achieved on the first application encouraged the operator to install a solid expandable production liner in a second well as part of the infilling campaign. The second application was in a well that had been sidetracked through a 7-5/8 in. production liner that was cemented up to a depth of 147m (482 ft). Approximately 430m (1,410 ft) of 6 x 7-5/8 in. solid expandable tubulars were deployed, cemented and expanded (Figure 2). The total time spent to run the casing, cement and expand amounted to 1.52 days. Production from this well is ~1,200 BOPD.
Case History #2 – Deepwater Mature Field Re-entry

A prime example of an innovative application was the solid expandable tubular system installed to simultaneously isolate a sour zone produced through casing perforations and segregate a previously repaired multi-stage cementing collar in a well in Gabon. The solid expandable cased-hole liner allowed the operator to develop a lower zone and continue producing from the existing well.

Approximately 430m (~1,415 ft) of 7-5/8 x 9-5/8 in. expandable cased-hole liner included 34 solid expandable tubular liner joints and seven liner hangers with elastomer seals. A slight modification to the system consisted of removing the top elastomer section on the number seven liner hanger to enable the snubbing slips to close if necessary. The liner assembly was positioned at ~1,700m (~5,580 ft) and expansion was initiated with 3,600 psi. Expansion pressure ranged from 2,000 to 2,500 psi with overpull between 30 to 50 klb.

The solid expandable tubular system successfully isolated six individual sets of perforations into four intervals in the Tchatamba South B2 sidetrack (TCTS B2st). This system also reinforced the integrity of a previously repaired, multi-stage cementing collar. A caveat to this installation was the fact that the operator used a hydraulic workover unit (HWO) in this well.
intervention as an alternative to a conventional rig (Figure 3). The increasing cost and unavailability of drilling and workover rigs have become contributing obstacles for well intervention and well repairs in mature fields. The installation of the solid expandable system with the HWO enabled the operator to perforate and produce a deeper zone.

The $1.5MM (US) savings realized by using the HWO unit and installing a solid expandable tubular system reduced the time to payout of the project. The operator avoided the loss of revenue of having to wait a year for a drilling rig, realizing another cost benefit of this operation. The initial production rate of 1,700 BOPD in July 2005 stabilized at 600 BOPD.
Case History #3 – Mitigating Depleted Zones in Deep Water

An operator with significant production stemming from an established field in the Gulf of Mexico identified another opportunity to produce more upstructure reserves. As a result, the operator developed a re-entry program for sidetracking an existing well to reach the updip deepwater objective. The original drilling conditions were similar to many deepwater prospects requiring multiple casing strings to reach the productive intervals with a directional wellbore drilled to 22,000 ft (6,705m) MD with 15 ppg mud. During re-entry operations, higher-than-expected pore pressures encountered at ~6,400m (21,000 ft) resulted in the loss of the original wellbore due to lost returns in the depleted sands. Mitigating the trouble zone required a solution that would enable the operator to reach TD without losing hole size.

A 7-5/8 x 9-5/8 in. openhole system over 2,092m (6,865 ft) in length—the longest solid expandable system expanded to-date—enabled the operator to drill through both overpressured and depleted sands to an intermediate and unplanned casing point. With subsequent drilling operations below the expandable liner, the operator reached the target zone and cased the well with a 7 in. flush-joint production liner (Figure 4).

By installing the solid expandable system, the operator achieved zonal isolation and maintained hole diameter. Reaching the TD with a large enough hole to complete with 7 in. flush joint rather than 5-1/2 in. production casing enable the operator to avoid the mechanical risks associated with 5-1/2 in. production casing and save over 5,000 BOPD production utilizing 7 in. casing.

A caveat to this installation was the development of a launcher capable to withstand the weight and pressure limitations associated with the drilling conditions. Design of the high-capacity launcher took into account the weight of the expandable liner, compressive/tensile load limits of expandable connections, expansion ratio, pressure/force required to initiate expansion, pull/push capacity of the inner-string, downhole conditions (mud weight, temperature, angles, dogleg, drag, etc.), and the amount of overpull required in case of a downhole-stuck situation. The high-capacity launcher successfully prevented premature expansion due to the liner weight, and the force margins were in place to mitigate the risk in case the liner became stuck and overpull was applied.
Deepwater #4 – ERD at 82° Inclination

The objective of this installation was to extend the shoe of the 9-3/8 in. base casing, which was stuck high. A 7-5/8 x 9-3/8 in. 39 lb/ft openhole liner was safely installed in the Gulf of Mexico in 2,945 ft of water. Several meetings between the operator and the service provider mitigated risks involved with installing a solid expandable liner into an 82° wellbore section. Ninety one joints of solid expandable liner were made up and run without any problems, as was the inner-string. The trip through the angled section of the base casing and into the open hole to bottom was executed without problems and closely matched the modeling conducted prior to the installation. The cement job was performed as planned and the dart was displaced and landed (494 bbl calculated and landed with 520 bbl). Expansion was initiated with 4,100 psi (full pick-up weight applied) and continued smoothly with an average of 2,400 psi. After expanding seven stands, a slight reduction in pressure was noted. After testing the surface equipment to confirm the loss was downhole, expansion was resumed with more mechanical force and less hydraulic pressure. Hydraulic pressure was regained completely with the last eight stands of expansion. After the cone exited the top, the entire liner was successfully pressure tested to 1,200 psi for 30 min. This installation demonstrates the ability of solid expandable systems to effectively address difficult drilling condition in deep water and in high-angle wellbores approaching horizontal.
Deepwater #5 – Window Exit

The objective of this installation was to complete the well with a larger production casing string. The expandable liner was part of the total well sidetrack by design and not a contingency. A 9-5/8 x 11-7/8 in. solid expandable openhole liner was safely installed in the Gulf of Mexico well in 5,380 ft of water. The liner was made up and run in the hole through a whipstock window at ~22,600 ft without any difficulties. The liner was taken into position slowly to mitigate surge pressures. The liner was worked through a tight spot with circulation and then run to the setting depth at ~27,000 ft. The well was circulated while the cement was prepared. The cement job was performed as planned. However, the dart did not land at the calculated volume. After waiting on cement to set for ~20 hours, the liner was successfully expanded mechanically. With a pre-expansion length 4,924 ft, the solid expandable system enabled the operator to gain one casing size at this point in the wellbore construction.

Deepwater #6 – Planned Ultra-deepwater Application

Operations conducted in deep water usually require an increase in vessel size and equipment capacity. Water depth, ocean conditions, BOP, and riser size all affect the size of the rig. Drilling margins, such as the difference between pore pressure and fracture gradient, narrow as operations move into deeper water. Narrower margins require more casing strings to drill to an equivalent depth below the mudline compared to a well drilled in shallower water or drilled on land.

While still in the project planning process, an operator incorporated two solid expandable tubular systems into the wellbore design to reduce the chance of unstable hole conditions during installation. The well in which these two planned systems were installed was in water depth ~2,440m (~8,000 ft) (Figure 5). The initial solid expandable openhole liner was installed below the 16 in., 84.0 lb/ft casing string set at ~3,600m (~11,800 ft). A 13-3/8 x 16 in. expandable openhole liner was set at ~3,870m (~12,700 ft). The second application consisted of ~460m (1,500 ft), 9-5/8 x 11-3/4 in. openhole expandable liner installed below the 11-3/4 in. drilling liner. These two successful applications enabled the operator to explore deeper objectives and ultimately reach TD with 8-5/8 in. casing.

The up-front planning made it possible for the operator to reach TD with adequate hole size and to mitigate downhole risk. Optimum hole size enabled the operator to log the well with
larger, more reliable tools. Planning solid expandable tubular systems high in the wellbore contributed to a significant reduction in flat time when compared with offset wells drilled in the area.

![Figure 5 - Conventional vs. expandable solid expandable tubular installation for an ultra-deepwater well.](image)

**Conclusion**

Further evolution of expandable technology has seen the development of more system sizes and more applicable options such as the 9-5/8 in. and 8 in. single-diameter systems. The 9-5/8 x 11-3/4 in. single-diameter system provides borehole stabilization and extends the shoe in what is commonly a crucial casing string. With no loss of ID, a subsequent 9-5/8 in. casing string can be run. The 8 in. system stabilizes the borehole without the need to cement or tie back into the base casing with a metal-to-formation expansion. This system provides a means by which to isolate problem formations and still maintain an 8-1/2 in. pass through and use a standard BHA to drill ahead.

As the case histories illustrate, solid expandable tubulars are a cost-effective alternative, a feasible contingency, and a substantial element in the well design to achieve varied objectives. Many of these applications have optimized the technology by seizing installation opportunity
rather than waiting on trouble-oriented need. This enabling technology facilitates turning previously undrillable and shut-in wells into viable producers.

Current and future environmental concerns and economic challenges for operators are forcing the industry to re-examine the drivers for exploring and producing hydrocarbons. Solid expandable tubular systems contribute value-added technology to drilling and workover operations to the extent that they maximize reservoir potential by reducing wellbore tapering and ensuring TD is reached in optimal hole size for evaluation and testing or production. In addition, solid expandable tubulars have helped maximize the rate of investment via leveraging capitalized assets and infrastructure. As the potential application realm continues to be redefined, the installation history has proven that solid expandable systems are adaptable and robust enough to be tailored to help meet the growing worldwide energy demand.

The resulting benefits and results in deepwater wells with solid expandable liners has proven the reliability of the technology and continues to increase confidence in application. Drilling engineers and well construction specialists that have incorporated solid expandable liners as part of the basis of design are reaping very promising results. Solid expandable tubular technology has enabled operators to drill in water depths that were once considered out of reach. As illustrated with a decade of success, offshore operations, regardless of depth, benefit from enabling technologies that are efficient and cost-effective such as solid expandable tubulars.

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