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AADE XXX: EXPANDING SOLUTIONS FOR IMPROVED PERFORMANCE

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Abstract

Solid expandable technology continues to broaden its potential with applications that produce significant performance improvements such as attaining zonal isolation without cement while retaining hole size. An operator was two years into a multi-well drilling campaign with 40 installations of the 6 x 7-5/8 in. solid expandable openhole liners for a slimmer well profile. This slim well design enabled the use of 10-3/4 in. surface casing while still reaching TD at approximately 15,000 ft with 4-1/2 in. casing. Although this design improved the rate of penetration and reduced overall drilling costs approximately $1M per well, the operator wanted to build on the success and increase the benefits. Formation characteristics and solid expandable tubular efficiency enabled employing swellable elastomers in the hard rock and eliminating the need for underreaming and cementing. Zonal isolation was achieved by setting the elastomers at the shoe of the expandable liner. The operator estimated that by dispensing with underreaming and cementing, an additional four to six days of rig time was saved.

Novel applications use the technology's hole conservation and zonal isolation capabilities to create better fracture stimulations, improve completions, and increase recovery. In a recent 2008 installation to maximize production ID for a multi-zone fracturing operation, an expandable system with swellable elastomers provided both the production conduit and zonal isolation. The system improved perforating efficiency, optimized coil and annulus flow area, and enabled higher injection rates and better fracture initiation. This paper explains why re-evaluating how to use solid expandable tubulars benefits drilling and completion operations. Case histories are used to illustrate the increasing application realm of solid expandable tubulars. This paper also describes how incorporating these systems into the initial well design optimize the possibilities and potential of the technology.

Introduction

When the first solid expandable system was commercially installed, the application possibilities focused on extending the casing shoe. Today, over ten years and 1,000 installations later, the technology is exceeding the theoretical potential and becoming a versatile reality. Openhole expandable tubulars have successfully mitigated downhole conditions such as equivalent circulating density (ECD) -related drilling problems, borehole instabilities, and narrow pore pressure/fracture gradient windows.[1] Cased-hole expandable systems have been used to isolate old perforated intervals, reinforce casing with substantial wall loss due to corrosion, and cover defective or leaking pipe.

Openhole systems that clad against the formation incorporate special expandable anchor joints with elastomeric bands that push into the formation above and below the problematic zone to provide an annular seal. A FlexClad system expands upper and lower "anchor hanger" sections, spaced accordingly with conventional or specialty API tubulars, and clads inside the existing casing.

The single-diameter system enables planning successive expandable liners with uniform ID to eliminate any telescoping of the wellbore or some portion of it. This advantage allows the entire well design and related drilling equipment, such as BOPs, risers, and rig size to be slimmed down. Standardizing the drilling program, including drillpipe, bits, mud/cement volumes, and rig sizing, helps lower drilling cost-per-foot and increase drilling efficiency.

Successive single-diameter liners can significantly extend current lateral reach to boost the recovery factor, enhance the production index, and increase reservoir contact. 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 and could extend drilling reach up to 50 percent.[2] In dynamic formations, the single-diameter system used in the open hole to clad over just the problematic formations eliminates the need and cost to cover an entire zone. Multiple casing points can be made up or initially attained without losing hole size.

State of the Technology

Solid expandable technology quickly became a valuable wellbore design element that put previously inaccessible reserves within reach. Installation demands and conditions prompted tool enhancements that made the expandable systems more robust and applicable.[3,4] Experience demonstrated that the most advantageous approach is to incorporate expandable systems into the initial drilling or workover plan as part of the well profile.[5]

As the technology evolved, so did the application realm. Significant success has been realized when solid expandable systems are combined with sidetracking operations. The conventional casing solution positions a window and sidetracks from previous casing. This approach often risks ID to TD when drilling continues. By positioning an expandable through the window exit, hole size is not compromised and casing points can be saved.

A slimmer well design is one of the more innovative applications of the technology. Incorporating solid expandables in the initial well plan enables reaching TD with a given size wellbore while beginning the well with a smaller hole. The "slimwell" approach also facilitates reaching TD with a larger hole than with a conventional casing design, or enables drilling further while still maintaining the required completion size. The well construction process is impacted even more by reducing expenditures on costly items such as the rig, the riser, and mudline equipment. In a conventional well with a telescoping casing string, changing out the BHA and changing to a smaller drillstring that accommodates smaller casing sizes is a time-consuming process. A "slimwell" design can minimize the number of times the drillstring size must be changed. These factors help reduce the spread rate and expedite a quicker payback on capital costs.

The Drilling Advantage

As a drilling tool, solid expandable systems have successfully mitigated unexpected challenges that required an prompt solution that integrated easily with the wellbore plan and preserved the operational investment and effort. Solid expandable systems have provided technically reliable solutions in the following conditions:

- HPHT environments
- Sub-salt sections
- Rubble zones
- Unconsolidated formations
- Shallow gas hazards
- Flows and losses
- Unstable hole sections
- Narrow pore pressure/frac gradient margin environments

Many of these applications have optimized the technology by seizing installation opportunity rather than waiting on trouble-oriented need.[6] Planning solid expandable tubulars into the initial design to achieve a larger wellbore at TD have resulted in the following advantages:

- Higher rate-of-penetration (ROP)
- Overall drilling cost savings using slimmed wellbore vs. big bore pipe program
- Improved drilling performance and lower equivalent circulation density (ECD)[1]

A Production Solution

Completion techniques have evolved to enable multi-stage fracturing programs over long horizontal wellbores that create more connectivity. Newer solutions separate the drilling, casing, and completion processes from the fracturing operations. These technical capabilities provide for better economics and result in project efficiencies by not tying up the rig for all operations. Expandable technology used as a completion/production string facilitates increased fracturing rates and additional fracturing options, resulting in improved conductivity and enhanced hydrocarbon production. Expandable tubulars can be used in re-entry wells to isolate old perforations, allowing for new zones, or new sections within zones, to be perforated and stimulated. A combination expandable and conventional liner or a full-length solid expandable system can provide an integral component in new wells or re-entry wells where low-permeability reservoirs, such as those characteristic of unconventional gas formations, require isolation and separation for selective or pinpoint hydraulic fracturing or re-fracturing.

Although successful stimulation is routinely attained from hydraulic fracturing, ancillary downhole tools such as conventional completion equipment often compromise results by restricting flow and affecting pressure performance. Solid expandable systems can optimize the fracturing parameters by maintaining larger diameters and providing seals for selective multi-zone or zonal isolation purposes. These production systems can consist of either solid expandable tubulars or expandable sealing sections combined with conventional tubulars using premium connections, thus providing a superior completion solution.[7]

Solid expandable tubulars installed inside existing casing reinforces the base casing with minimal loss of ID. Because the mechanical properties of expandable tubulars are similar to the base casing a more long-term solution is probable. Repetitive repair operations, such as a cement squeeze (a short-term fix), are eliminated.

When expandable systems are installed as part of a rejuvenation project, the well is capable of a higher level of production than before by increasing the measured depth of the well vertically or at an angle (sidetrack). Using expandable systems with sidetrack operations enable deepening, extending, or re-directing existing wellbores without compromising hole size. The new wellbore can capture production in new targets, by-passed pay zones, or behind pipe reserves.

Case Histories

Drilling engineers that "think outside the box" have found that solid expandable systems bring value as a creative solution for a variety of challenges. As an enabling technology, solid expandable tubulars provide an efficient means to preserve hole size, especially in deepwater where wellbore tapering can hinder completion. But recent applications and system enhancements illustrate how the technology has become an adaptable tool that improves performance, whether for drilling, completion, or production operations.

Field Development

An independent operator with a large gas field in Central Texas needed a technical solution to develop the field as economically as possible. With plans to drill extensively in this field over several years, the operator realized that any cost-per-well savings would extrapolate into huge savings for the project.[1] Field development challenges included determining the maximum number of wells that could be drilled while reducing the cost per well, despite the rising costs of services. As an example of the rising costs, in the first six months of field development, rig rates had increased approximately 40%. To combat rising rig rates, the time spent drilling each well needed to be reduced. The major culprit of time consumption, an intermediate section of 12-1/4 in. hole, had proven to be problematic in previously drilled wells in the field. Eliminating the need for this size of hole section would greatly increase the efficiency of drilling operations. As a challenge, however, a minimum of 4-1/2 in. production casing was required to facilitate the high gas flow rates of this field.

After drilling several wells with a conventional big-pipe design, a slim well design was implemented. Incorporating a 6 x 7-5/8 in. openhole solid expandable system into the wellbore plan enabled drilling a 14-3/4 in. surface hole instead of a 17-1/2 in. hole, allowing drillout of surface pipe one day earlier. Below the surface pipe, the operator drilled a 9-7/8 in. hole (drilled at 3.0 days/1,000 ft) versus a 12-1/4 in. hole (drilled at 4.8 days/1,000 ft). The solid expandable liner was then run below this section, allowing for 4-1/2 in. production casing at TD to facilitate planned production rates (Figure 1).

Overall results showed a reduction in total drilling time to target depth by 19 percent, from 89 to 72 days. In addition to cost savings from reduced drilling time, further cost cuts could be realized by using water-based mud due to the improved hole cleaning dynamics. Using water-based mud saved money in both environmental and disposal costs. Evaluation of total savings per well showed that the solid expandable system reduced total drilling costs by $79 per foot, approximately $1M (USD) per well. From a field development perspective, these savings translated into every fifth well being drilled at no cost and four free wells per year. Additionally, reserves could be brought online faster accelerating production.

Two years into this multi-well campaign drilling HPHT formations, the operator decided to build on the success and enhance the benefits. Previously, installation of the solid expandable systems required underreaming the 7-1/4 in. hole section. In this particular installation a 6-3/4 in. section was drilled without underreaming. An expandable joint with swellable elastomers was installed above the launcher to provide zonal isolation, thus eliminating the need for cementing. Zonal isolation was achieved by setting the elastomers at the shoe of the expandable liner.

Formation characteristics and solid expandable tubular efficiency enabled employing swellable elastomers in the hard rock and eliminating the need for underreaming and cementing. Although underreaming or hole enlargement is usually a requirement when running expandable systems, this liner did not require a cement job, and therefore the hole size required could be minimized. The elimination of underreaming requirements and the need to cement saved another four to six days of rig time, equating to an additional ~$300,000 (USD) in savings.

Window of Opportunity

A string of successes provided a level of confidence for this same operator when an alternate plan was needed in another well in the same field. After expanding a 6 x 7-5/8 in. openhole liner and drilling ahead as planned, a change of hole direction was required to better access the pay zone. To avoid losing precious hole size, sidetracking operations were designed that capitalized on the reliability and versatility of solid expandable tubulars.

After plugging the vertical hole with cement, a whipstock was set above the initially expanded openhole liner. A window was cut in the conventional 7-5/8 in. casing. Over 800 ft of solid expandable tubulars were run through the window into the open hole. This expandable installation used the same approach that had been applied in the previous wells – attaining zonal isolation with swellable elastomers and eliminating the need to underream. The openhole liner was expanded through the window with approximately 200 ft of overlap in the 7-5/8 in. base casing. After drilling out the shoe with 5-7/8 in. bit, drilling continued with a directional assembly without compromising hole size.

A Diagnostic Enabler

When an operator in Canada embarked on a program to develop the upper zone of the Debolt formation, the vertical well profile used successfully in the lower zone proved inadequate. In three vertical wells, programmed fracture placement was inconsistent. This drilling approach also resulted in inconsistent performance and jeopardized economic viability.

It was decided that the tight carbonate upper zone would best be drilled and completed horizontally. To confirm this approach, solid expandable tubulars with swellable elastomers and coil-tubing technology were combined. The goal was to isolate multiple zones, optimize casing diameter to reduce friction and surface treating pressure during high-rate fracturing, and implement a flexible fracturing process for operational contingencies.

The horizontal well targeted a low permeability carbonate formation at about 7,385 ft MD at 4,644 ft TVD. A single 5-1/2 x 7 in., 26.0 lb/ft openhole expandable liner with five sections of swellable elastomers was installed and expanded (Figure 2). All hydraulic fractures were successfully placed and effective zonal isolation was observed by micro-seismic imaging.

This installation brought significant value as a diagnostic tool to help develop drilling and completions strategies for this regional play. The solid expandable system enlarged the ID by 36 percent or approximately 1-1/2 in. over a conventional stimulation liner. Deploying coiled tubing increased operational contingencies during hydraulic fracturing. Improved flexibility enabled meaningful evolution of the fracture design to occur during fracture treatments. This deployment significantly increased the hydraulic fracture placement success rate.

Conclusion

Solid expandable systems used as a well construction technology has helped mitigate challenging conditions as well as optimize the benefits of the technology. The successful application of solid expandable systems in a variety of environments and areas has given well designers, geologists, and production engineers viable options that can generate significant value during the planning, drilling, and production phase of any project. Conservation of valuable hole size is attained when these systems are used proactively by incorporating them into the initial wellbore design and to save casing points when unexpected troublesome formations are encountered.

The installation records for these systems are as wide as the application realm and exemplify the adaptable nature of the technology. Solid expandable systems have facilitated reaching and producing reserves that previously were inaccessible due to drilling conditions and economic constraints, provided flexibility for exploration-well uncertainties, reduced well costs with a slimmer well design, and improved production performance in new drills and re-entry projects. The solid expandable liner technology's adaptability has led to it evolving from being used primarily as a last resort solution to an integral basis of design in well plans either as a drilling or production strategy.

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Figure 1: Solid expandable technology enables slimmer well design while using swellable elastomers and eliminating underreaming operations.

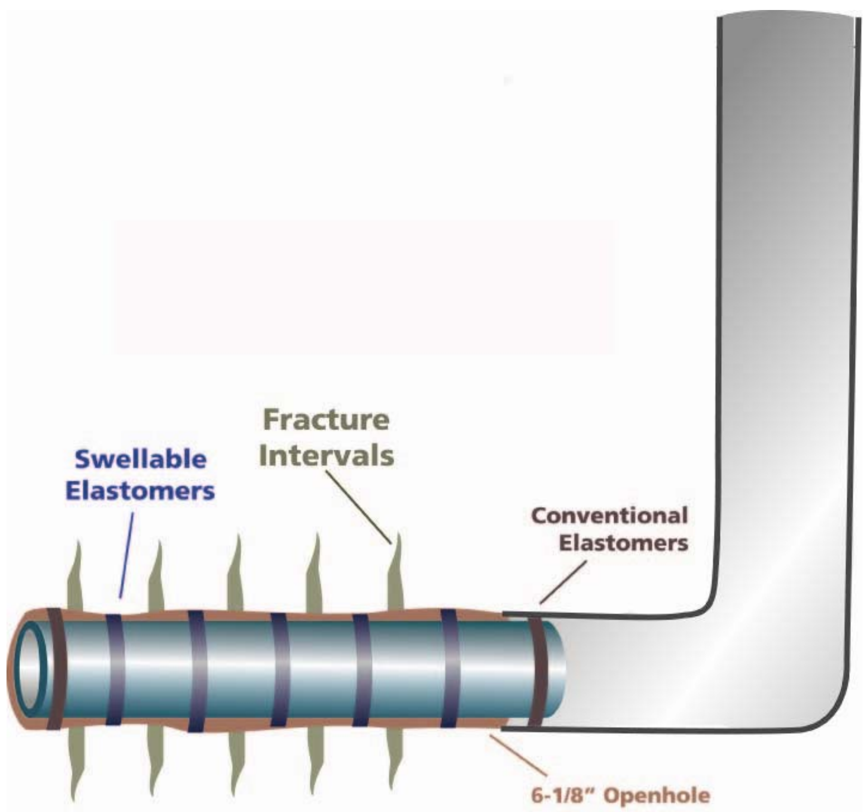

Figure 2: Five swellable elastomers on a 5-1/2 x 7 in. solid expandable tubular system achieved zonal isolation and facilitated accurate placement of hydraulic fractures.