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Inventive Solid Expandable Tubular Applications Capitalize on Window of Opportunity: Openhole Liner System Prevents Loss of Hole Size in Sidetracking Operations

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Abstract

The sign of any dynamic technology is its ability to continuously redefine and extend its application scope. Such is the case with solid expandable tubular technology that has been applied successfully in a variety of conditions and scenarios that include high-angle wells, deepwater wells, multiple installations in the same well, situations that require a relatively long expandable casing string, and various cementing designs.

Solid expandable tubular technology was developed originally to address drilling challenges in high pressure zones, deepwater environments, and for the repair and mechanical enhancement of existing casing strings. With nearly 300 system installations, their value, reliability, and diversity have been established and augmented with innovative applications. A notable example of expanding the application spectrum is the use of openhole liner systems in sidetrack window exits and through milled sections.

This paper will describe the design process, installation procedure, and value added of using solid expandable tubulars in sidetracking operations and through milled windows. Case histories will be used to define actual conditions and results of these applications. In addition, this paper will demonstrate how these enabling systems can be used more than once in the same wellbore but in different capacities, further illustrating the technology's resourcefulness.

Introduction

The evolution of solid expandable tubular systems is reflected in technical enhancements as well as broadening its applicable use. The basic principle of solid expandable tubular technology is cold-drawing steel tubulars to the required size downhole. After the liner assembly is run in the hole, a dart is pumped through the drillpipe until it seats in the shoe of the assembly. Seating of the dart provides a pressure seal and enables the pipe to be expanded hydraulically or mechanically. An expansion cone mechanically deforms the pipe permanently. The cone moves through the tubular by a differential hydraulic pressure across the cone itself and/or by a direct mechanical pull or push force. The progress of the cone through the tubular deforms the steel past its elastic yield limit into its plastic deformation region, stopping short of its ultimate yield strength.[1] Solid expandable tubulars have been modified for corrosive well installation, introduced into deviated and horizontal wells and have proven to be an advantageous asset when coupled with surface stack technology.[2] In addition to applications that display the systems' versatility, its adaptability was demonstrated with the successful expansion of solid tubulars through window exits and milled sections.

Conventional tubulars and tools used in sidetrack operations, executed either for corrective measures or for recompletion, result in the loss of an entire casing size. The loss of ID (internal diameter) in the production zone restricts the potential oil flow and decreases the well's economic viability. To mitigate the reduction of ID, a procedure was developed to expand casing off a whipstock through a window exit to deliver an optimized ID (Figure 1).

An expandable openhole liner system provided hole optimization and a cost-effective method to reactivate an offshore field from older platforms with no remaining template slots.[3] Recompleting a deepwater well from a tension leg platform through a riser was achieved by running an expandable system through a milled-casing window using a smaller production riser. Running this enabling technology through a whipstock window allows operators to use existing facilities while still maintaining a larger ID for recompletion and stimulation. This solution provides the means for turning a tubing-constrained completion into a bigbore producer (Figure 2), whether the result of a re-entry or a new drill.[4]

Operative Conditions for Sidetracking

The initial installations of solid expandable tubulars primarily consisted of casing remediation in vertical wells. Subsequent applications of the technology revealed its expansive functionality in a myriad of conditions and circumstances. Each successful installation of solid expandable tubulars to retain hole size inevitably lead to the conceptual consideration of using the systems in conjunction with whipstock technology.

Developing a process to apply the technology in sidetracking operations required identifying criteria that directly affects or has significant bearing on the equipment and conditions. Considerations identified included the following:

- Dogleg severity across the whipstock face and the openhole interval drilled past the whipstock window
- Base casing size and connection
- Type and size of whipstock
- Length and configuration of the whipstock window
- Quality of milled window
- Stiffness of the expansion assembly

An operative aspect to apply solid expandable tubulars through a whipstock window necessitates adherence to particular preparation considerations. Because the configuration of the casing exit is a defining criterion for a successful application, an additional milling run may be required to provide adequate window conditioning to finish dressing the window shape and facing, and minimize damage to the system (Figure 3).

Equipment providers have whipstocks with extended blade lengths that reduce the dogleg severity at the whipstock window. The condition of the edges of the window should be smooth to minimize gouging on the outside of the solid expandable casing. A well plan with lower dogleg severity allows for easier expansion and less stress on the threaded connections of the expandable pipe. Identifying the criteria, formulating a process and successfully implementing expansion has contributed to the reliability of this technology and increased operator acceptance. Currently, 14 solid expandable tubular systems have been installed in sidetrack operations and three through milled sections.

Case History 1

A major operator in the Gulf of Mexico installed a 9-5/8 x 11-7/8 in. openhole liner system to isolate low pressure zones below an 11-7/8 in. window at ~11,500 ft. A 10-5/8 x 12 in. bi-center bit was used to drill through depleted sand and prepare the window for the expansion system. After pulling through the window, subsequent trips back through the window showed little or no drag. The ~3,000 ft expandable liner system, consisting of 75 joints of pipe, was run in the hole. Using a tapered guide, the solid expandable liner started in the hole. As the launcher (at the bottom of the liner) went through the whipstock window in the 11-7/8 in. liner, no additional drag was recorded. There were no obstructions as the liner was run to bottom. A pickup weight of 495,000 lb and slackoff weight of 350,000 lb was recorded just off the bottom.

After cementing, the top drive was screwed in and displacement of the dart began. The dart was seated with 6 bbl/min and 1,800 psi. The pressure was held for ~1 minute and then released. Expansion was initiated with ~2,500 psi and proceeding smoothly. Stand number 31 marked the first stand expanded through the window. Expansion pressures ranged from 1,800 to 2,200 psi. The liner was pressure tested to 1,450 psi for 30 minutes.

The successful installation of this system through a window enabled the operator to isolate the low pressure zones and reach the target without compromising hole size. The well was completed as a successful producer.

Case History 2

An operator in the Middle East required a solution in a horizontal well to isolate a zone from overlying water-bearing formations. To prevent water influx into the wellbore, ~1,350 ft of 5-1/2 x 7 in. openhole liner was installed to case off the angle-build section of this well.

A window was cut in the 7 in. liner and an additional 15 ft of new hole was drilled to prepare the hole for installation. A steerable assembly was run and kicked off the 8°/100 ft build section with a 6 x 7 in. bi-center bit. A near bit reamer completed opening the 7 in. hole to ~7,400 ft. Two stacked string mills on a clean-out/dummy drift assembly were run in the hole and worked through the window until no torque was noted.

After making up the inner-string to the expansion assembly, the solid expandable system was run in the hole on 3-1/2 in. drillpipe to ~7,400 ft. The running sequence for the openhole system consisted of the launcher with a 6-ft pup joint, 32 joints of expandable pipe, an anchor hanger and a tapered guide. Once the expandable openhole liner was in position, the dart was dropped and was seated with 500 psi above the final circulating pressure. Expansion was initiated with 5,200 psi. The average expansion pressure measured 4,200 psi with ~4,600 psi expansion pressure through the connections and also through the elastomer sections of the anchor hanger.

The expandable liner was installed by expanding in the open hole, across the 8 ft window of the whipstock and finally anchoring in the 7 in. liner. The top of the liner was then successfully pressure tested to 2,000 psi for 30 minutes. Following the liner installation, the shoe of the liner was drilled out and the three laterals that had been drilled in the open hole past the end of the liner were opened for production.

Case History 3

Another system application that epitomizes the versatility of the technology was the expansion of a 4-1/4 x 5-1/2 in. openhole liner through a milled section of 5-1/2 in. base casing to be used as a production liner in a well in China. Previous perforations in this well were from 60mm gun shots that are shallow and small, and a 63mm gun that causes falling debris in the hole. Results from both of these perforation sizes are detrimental to completion operations. Approximately 1,300 ft of solid expandable pipe, comprised of 35 joints, a shoe joint and an anchor joint, was run to preserve hole size. The first 30 joints were filled with clean mud while the last five joints remained dry to prevent overflowing the liner when the inner-string was run.

The expandable system was run to ~7,300 ft after which the cement operation was performed. The dart was displaced, landed and pressure was increased to initiate expansion. Expansion pressures ranged from ~3,600 to 5,200 psi. The cone exited the top of the liner and the liner, including the elastomer seal between the expanded liner and the base casing, was successfully tested to 2,175 psi.

Using the 4-1/4 x 5-1/2 in. expandable system as a production liner in this deviated well resulted in the operator reaching the target zone with greater production tubulars than would have been available if a conventional 3-1/2 in. liner had been used. As a result of the solid expandable tubular installation, the operator could select the production zone (using a 100mm packer) and use an 89mm perforation gun and 76mm oil tubing for development.

The following month, this operator used a 4-1/4 x 5-1/2 in. openhole liner in another well in the same field to preserve hole size through a milled section. That installation resulted in a similar completion success.

Case History 4

Another well in the Middle East exemplifies the value of solid expandable technology's resourcefulness when two different systems were installed in a single well. The first application consisted of a 5-1/2 x 6-1/8 in. openhole cladding system installed to isolate water-saturated loss zones in the toe of a horizontal barefoot producer. This system, ~167 ft in length, was run to a depth of ~3,600 ft for expansion through a window cut in the 7 in. liner. The expansion of the liner was initiated with ~4,600 psi, with propagation pressure ranging from ~4,000 to 4,800 psi.

With the openhole clad in place, preparation commenced for installation of a 5-1/2 x 7 in. expandable openhole liner to isolate the window cut through the 7 in. liner. The installation required ~600 ft of solid expandable pipe to re-establish the shoe at ~2,800 ft. This installation was to be across the high build section that measured 10°/100 ft. Although these systems have been qualified for expansion through dogleg severities up to 15°/100 ft, the decision was made to initiate expansion ~165 ft below the setting depth where the dogleg severity was a more moderate 2 to 3°/100 ft.

The openhole liner was run in the hole to ~3,000 ft where expansion was initiated with ~4,000 psi. The operation was halted after ~3 ft into the next joint to ensure that the expansion cone was past the launcher but had not expanded the swelling elastomers of the anchor hanger that had been placed near the bottom of the liner assembly. The end of the liner was then pulled up to ~2,800 ft and expansion resumed. This operation demonstrated the ability to initiate expansion, stop prior to anchoring, reposition the liner and successfully resume and complete expansion.

Value Proposition

Reaching a lower horizon with expandables through a sidetrack eliminates an extra string of pipe coming out of a window. Successfully expanding solid tubulars in sidetrack operations opens up the possibility of exploiting the resources of an entire field with fewer wells. These systems and the expansion process contribute value-added technology to drilling operations to the extent that they

- Reduce well Authority for Expenditure (AFE) cost by optimizing the rate of penetration (ROP). The ROP increases because expandables provide the ability to drill
- with larger, stronger, more competent drillpipe and accessories (bits, motors, MWD (measurements while drilling), etc.).
- Maximize reservoir potential by
    - Ensuring target TD (total depth) is reached in optimal hole size for evaluation and testing or production.
    - Accessing deeper reservoirs which are unreachable economically with other available technology.
- Maximize rate of investment via leveraging capitalized assets and infrastructure by preserving hole size in sidetracking programs and through milled sections.

Conclusion

The use of a whipstock to bypass obstacles or unstable formations creates a potential hole loss situation or well plan detour. The window exit capabilities of solid expandable tubular technology provides several benefits to the drilling process that include the following:

- Eliminates cutting and pulling casing, and re-drilling hole section
- Eliminates section milling operations
- Allows the operator to stay closer to the production zone

For a proper window exit installation and expansion, certain tool configurations must be factored into the process. The main issues regarding tool configuration include the dogleg severity of the whipstock, the condition of the window, and the absence of debris near the window. In most applications, an extended length whipstock tool will provide an acceptable dogleg severity. An additional milling run may be required to provide adequate window conditioning to minimize damage to the solid expandable system.

As solid expandable tubular technology continues to evolve through refined processes and enhanced equipment, the application envelope extends to more challenging conditions and extreme environments.

Providing a viable drilling option for these situations further defines how this enabling technology contributes a practical value-added proposition to the operator's bottom line.

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Figure 1 – Example of solid expandable tubular deployment in conjunction with whipstock technology.

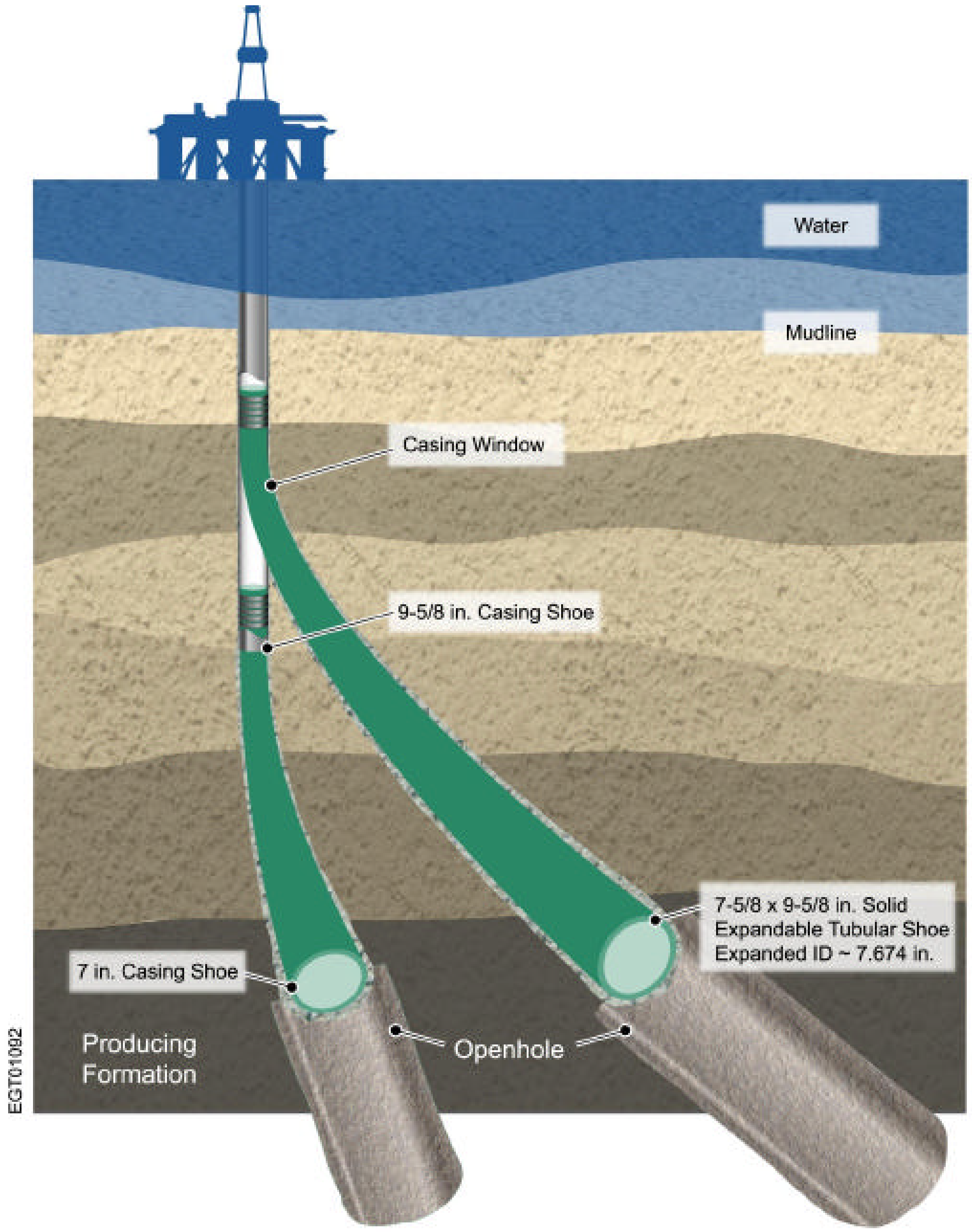

Figure 2 - Bigbore multi-lateral sidetrack.

Figure 3 – Inadequate window conditioning. Jagged edges create the potential for severe damage to the solid expandable tubulars.