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Expandable Casing Technology: Base of Mono-Diameter Borehole Concept

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Abstract

Since the first oil well was drilled, there has been one hard and fast rule of casing design: each string of pipe had to be able to pass through the previous string. Standard casing strings allow for annular room between casing strings. This rule has caused a number of problems throughout the history of the industry, ranging from simple inconvenience to premature abandonment, loss of reserves due to pressure losses, the inability to complete an exploratory well, thus the loss of an expensive offshore lease. Operators faced significant loss of inner diameter in the course of the normal drilling process, during re-entry and deepening of existing wells, or when installing additional casing strings to remediate well problems thus leading to limited exploration and production of oil and gas. The industry confronted this dilemma with innovative problem solving that stretched the boundaries of physics in the guise of solid expandable tubular technology.

As this tubular system moved from its infancy and discovery phase into one of a more adolescent technology, successful applications proved its reliability in a variety conditions and environments. Solid expandable tubulars continue to build a legacy as a solution to problems involving gas shut off, subsidence repair, water shut off, lost circulation, and remediation of wells slated for abandonment. Production casing can be run inside the expanded form of casing with the same diameter with this concept. It will allow, for the first time, casing to be set at will or as needed without a penalty in completed depth. Swelling shale and other drilling problems can be put behind pipe as necessary without jeopardizing planned total depth. Total depth limitations will now be limited primarily to mechanical capabilities of the drill rig, casing, and/or drill pipe run into and out of the borehole.

This paper will discuss solid expandable tubulars from theory to reality, following the technology from its inception through development to application. Case histories will be cited to illustrate how solid expandable tubular systems are applied in a myriad of drilling challenges. The paper will also discuss how the technology continues to evolve, leading to the mono-diameter well where casing diameter remains constant throughout the total length of the well which is highly economical.

Introduction

To understand the enormous potential value of expandable tubular technology, one must first understand the concept of telescoping well design and the constraints it places on conventional drilling.

- Telescoping well design:

During the planning stages, one of the primary considerations that the well engineer takes into account is the density (or "weight") of the drilling fluid. It must be heavy enough to suppress any pressured fluids contained by the rock (thus avoiding a blowout), and light enough to avoid breaking down the rock itself. Both parameters generally increase with depth, and create a window between which the drilling fluid density is safe. However, the mud density required to suppress fluid pressures at 9000' would usually break down the formation further up the well at 1000'. Therefore, the well is drilled in sections by running casing strings to cover depth ranges between which the required mud densities are suitable for the entire range. However, each bit must be smaller than the previous casing string, which in turn has to be smaller than the previous hole.

This requirement of well design creates a well where each hole section is ever-decreasing in diameter. The only conventional way to combat this effect is to start with an enormous hole at the top (sometimes 30") in order to run five casing strings and still end up with a 6" hole in the targeted reservoir. And this well design leaves little room for error: if the drillers are forced to run a casing string on account of unexpected formation pressures then the target formation may be impossible to reach. Thus there is an enormous carrot in a casing system that loses minimal - or possibly no - diameter while still isolating a whole section. Many current systems have the aim of producing a mono-bore well, that is, a well with a single diameter from top to bottom. But the shallow wells can the drilled with uniform diameter.

Technology

To reduce the loss of diameter each time a new casing string or liner is set, a cold working process has been developed whereby the casing or liner can be expanded by up to 20% in diameter after being run down-hole.

For this purpose, an expansion tool that exceeds the inner diameter of the tube by the required amount of expansion is forced through the pipe. This is done either hydraulically, by applying mud pressure, or mechanically, by pulling the conical/tapered expansion tool. The expansion needs to be reliable, when expanding several thousand feet below the surface. This can be from 30–6,000 ft. in length.

Carey Naquin was responsible for the first commercial and successful application of expandable tubular technology. Though the idea of expandable casing is elegantly simple, the process is complex and involves many fundamental mechanisms. Addressing the requirements of these first three expandable tubular applications has required much work. The solutions that the technology offers are presently based on analytical modelling, laboratory tests, and large-scale field tests using modified flush connections and new mandrel (pig) designs. These tests have resulted in important breakthroughs and demonstrated the feasibility of expanding Oilfield Country Tubular Goods (OCTG equipped with threaded connections.

While it is impossible to experimentally test all the parameters that an operator can face, many man-years of analytical and experimental testing have resulted in the ability to first, expand automotive-type metals, then apply that knowledge to the expansion of OCTG. Progressing from proof of concept to field readiness required additional analytical and experimental testing. Extensive numerical modelling with commercial finite element codes has been performed. It has become possible to obtain conclusive experimental results on tubular expansion only after a simple analytical model had been developed and the fundamentals of tubular expansion were analysed for a wide range of parameters. It then became possible to run carefully selected numerical models. This resulted in a solid experimental design that proved to be successful.

Applications

The applications can be grouped into two main categories – Cased hole and Open hole. Cased hole work is mainly down during the work over or completion phase of a well. The open hole products are used during the drilling period of a well.

The products developed and available today in cased hole work are the expandable liner hanger and the cased hole clad. The expandable liner hanger is basically an evolution of existing equipment currently used in the oil industry, a product with better thru bore and envisaged higher reliability. The Case hole clad provide a casing patch across a damaged section of casing, or to close off previously perforated casing. This product has two main advantages – minimal through bore loss [basically two times the wall thickness of tubular being expanded] and high pressure integrity performance.

Open hole applications is where expandable technology brings real advantages to the operator. Currently the products available are open hole liner and open hole clads.

Case Studies

1. A perfect example illustrating the benefits of solid expandables is a well in the Gulf of Mexico shelf with a target depth below 20,000 ft. A sidetrack out of the 11-3/4 in. casing provided an optimal exit, but restricted options to keep the planned hole size at TD. By planning in a 7-5/8 x 9-5/8 in. expandable system, the operator extended the 9-5/8 in. shoe thereby adding the additional casing string needed. The well was completed with the proper ID to enable evaluation (discovering ~150 of pay). Not only was this the longest solid expandable installed to date at 6,935 ft., but it was also the first time swell-able elastomers were used on the expandable system in the Gulf of Mexico (ensuring a successful leak-off test).

2. Another installation in a deepwater well provided assurance of reaching TD with the required ID. The well had been troublesome, requiring the 9-5/8 in. casing be set high. By installing a 7-5/8 x 9-5/8 in. expandable system, the operator was assured hole size for utilizing full-size logging tools. This particular installation is one of the deepest - the solid expandable shoe was set at nearly 30,000 ft.

Planning For Success:

Because an expandable liner is often installed in challenging wellbores, the key to maximizing value lies in planning. In the two examples above, the operator and service provider partnered to ensure a successful installation in challenging wellbores. The first (shelf) well utilized the liner as a part of the wellbore architecture - reducing contingency costs and ensuring a successful installation. The second (deepwater) well planned the liner in as a contingency, thereby reducing the risk of not reaching TD with the required ID.

Future Systems, New Solutions

Enhancements to the standard expandable systems include high-performance technology which enhances the liner's burst and collapse ratings. This is especially important as operators push deeper into higher pressure and temperature regimes. For instance, an exploratory well might encounter unexpected formation pressure changes. Or a re-entry well may need to drill through a depleted zone with high differential pressures.

A high-performance expandable system recently installed provided a novel solution. An operator side-tracking through an existing wellbore had compromised 13-3/8 in. casing due to wear. The high-performance liner reinforced the weakened area, ensured pressure integrity and the operator's success in continued drilling.

Conclusion

Challenging environment and conditions continue to drive the development of new technologies. Installing expandable casings in workover applications is an evolving industry trend. Technical advancements with expandable liners have finally bridged the gap in the wellbore construction process. The success achieved with the use of solid expandable tubulars in workover has created a new mainstay well construction option for operators worldwide.

There have been few instances within the well construction part of our industry in which a single new technology has displaces an existing proven technology. The petroleum industry takes a very conservative approach to the adoption of new ideas. However, the last decade saw the adoption of many new technologies in the upstream oil and gas sector. The challenge now is to maximise the potential of solid expandable tubulars in mainstream wellbore construction.

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Figure1: Conventional drilling versus Mono-Diameter well concept.

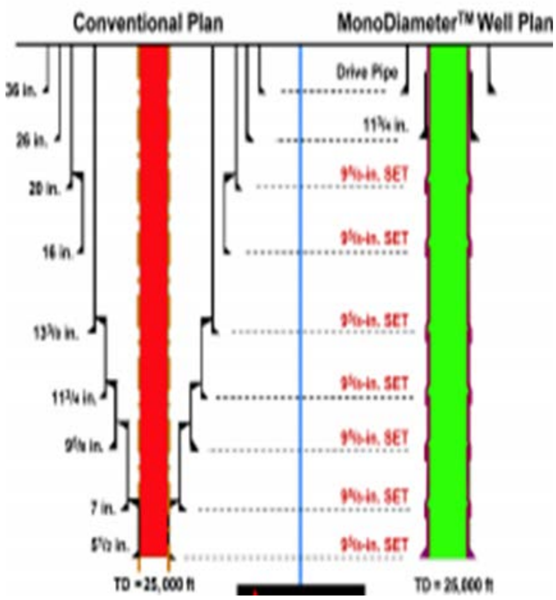

Figure2: Installation sequence for an expandable open hole line system.

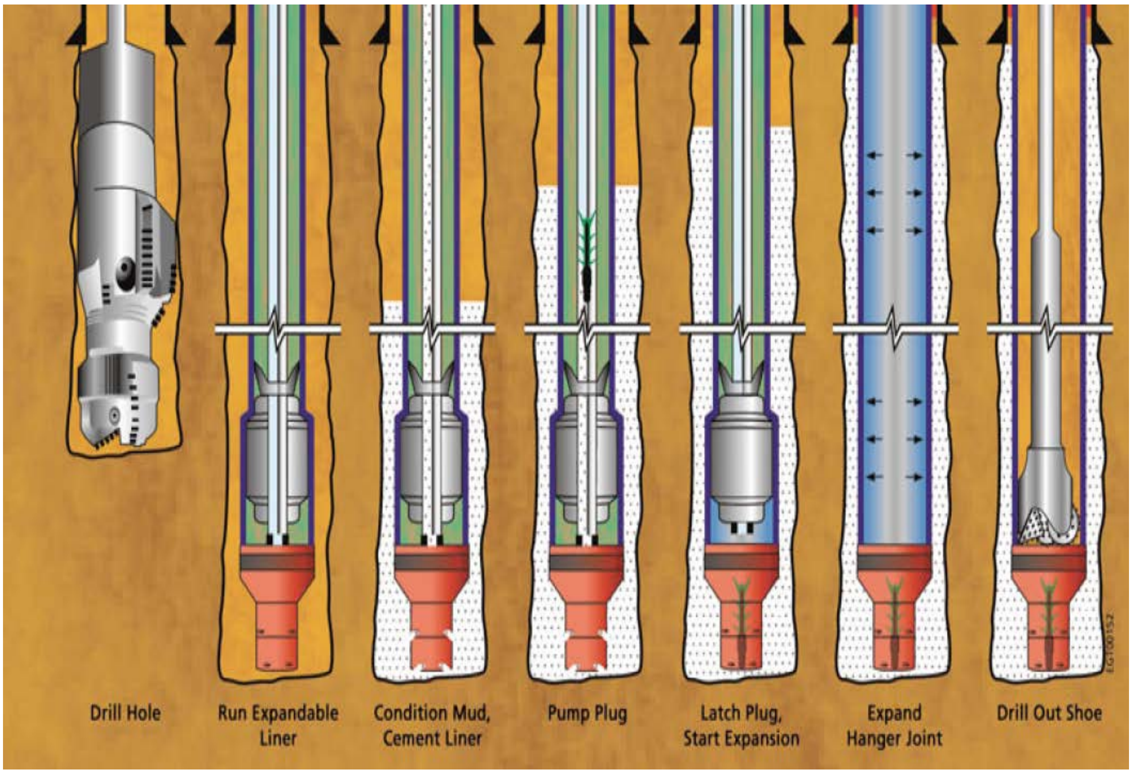

Figure3: Permanently deforming of pipe takes place in cold working condition**.**