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Development of a Monobore Casing System

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Abstract

The introduction of expandable metal technology to the oil and gas industry in recent years has allowed a change in the traditional well construction design. The advent of this technology is allowing operators to drill wellbores that do not subscribe to the traditional telescoping reduction in casing sizes as well depth increases. This capability will allow deep wells to be drilled without sacrificing well hole size, which has many advantages, ranging from wellbore construction costs to greater production potential. This paper will outline the development of a monobore well system covering material selection criteria to system development including field trials and commercial applications.

Introduction

The ability to drill wellbores that do not subscribe to the traditional telescoping reduction in casing sizes as well depth increases will allow deep wells to be drilled without sacrificing well hole size has many advantages over the traditional telescoping, reducing ID (internal diameter), wellbore construction method.

A primary benefit of the monobore well is the ability to reach the desired drilling depth with out having to sacrifice casing size. (Fig. 1) This capability could in theory allow for much deeper or deviated wells to be drilled due to the elimination of the hole reducing aspect. Further, should an unexpected hole problem be encountered while drilling, a monobore well design allows the ability to set a section of casing across this problem zone and continue wellbore construction without once again sacrificing hole size. This capability could ultimately allow the reservoir section of the reservoir to be entered with the initial size diameter production casing and thereby maintain the production capability that would have been comprised had a smaller size casing been used to enter the production zone.

In developing wells from the surface to total depth utilizing the monobore design, it is possible to reduce the size of surface equipment, such as wellhead, along with the overall size of the well's casing program. The use of smaller size equipment and casing may translate to direct cost savings.

General Back Ground Expandable Material and Expansion Methods:

The use of expandable metal technology to construct a monobore well requires the selecting of the correct material and method of expansion to achieve desired expansion percentages and final performance properties. The performance properties are not only measured in empirical numbers such as burs/collapse/tensile rating but also in ability to provide a suitable solution to an application. Both these factors must be developed and analyzed in unison in order for a system to perform as expected.

General Expandable Material Selection Overview:

Material selection for use in expandable application is evaluated and tested in regards to how it performs pre expansion, during the expansion process, and post expansion. The criteria used most commonly to classify and capture these material properties and performances in the three states are: toughness, work hardening, and the Bauschinger Effect.

In the pre expanded state the main criteria for an expandable material is its ability to resist tearing during the expansion process as a result of external marking which may develop during shipment, handling or installation. The materials ability to resist tearing is quantized as ductility or "notch toughness". This resistance to tearing is important because if an expandable material receives exterior marking or galling these areas could develop concentrated stress risers when the material undergoes expansion. These stress risers can develop during the expansion process, resulting in preferential yielding of the pipe at an isolated location and often resulting in rupture or expansion failure.

The ability of material to withstand the expansion process and the final characteristic of this material after is the main criteria for selecting a material for use in an expandable system. As a metal material goes from a pre to post expanded state it under goes isotropic hardening as can be seen in a typical tensile stress/strain curve. This isotropic hardening adds to the materials final tensile strength and burst capabilities. (Fig. 2)

In order for the material to transform to the final state its ability to “flow “without exceeding its True Ultimate Tensile Strength is defined by the materials True Strain which can translated to a %elongation to fracture. The selection of a material that has good elongation, the higher the better, properties balanced with final yield strength is the main parameter behind material selection for use in expandable products. (Fig. 3)

Countering the final collapse rating of expanded metal material is a reaction called the “Bauschinger Effect”. This is an effect which lowers the final collapse rating of the material as compared to its theoretical calculated value. This reduced rating is a result of stored residual stress following tensile plastic deformation. This affect, known as kinematic hardening, has been successfully characterized by multi-cyclic tensile/compression testing of expanded materials. (Fig. 3)

To counter this reduction in collapse rating a technique known as strain aging has successfully been used to recover properties of low alloy steels. Strain aging is performed at very low temperatures, similar to those experienced in many producing oil well installations. Due to the inconsistency of many downhole environments, it is impractical to think that complete recovery of a post-expanded tubular has been achieved consistently throughout its entire length. This reduction in collapse rating must therefore be factored into all expandable designs. (Fig. 4)

The corrosion resistance of expanded material in the post expanded state is another parameter which may be of importance in certain well applications. Material that may be corrosion resistant to certain well conditions in its pre-expanded state may not be post expansion. This possible corrosion susceptibility relates to the expansion process introducing increased grain dislocations leading to increased generalized pitting attack occurring. Increased grain dislocations (cold working) can also lead to an increased susceptibility to environmental cracking under certain downhole conditions. The industry is actively working towards qualifying new, post-expanded materials for operation in hostile well bore environments.

Other factors that are included in the selecting of materials include: microstructure, material cleanliness, alloy composition, and quality of material finish. The microstructure of a material is evaluated in the areas of homogeneity and grain dislocation and transformation. Material “cleanliness” includes evaluations of the types of inclusions in the material and secondary precipitates. Alloy composition of the material can be specified to help with factors pertaining to rate of work hardness and increasing the toughness. And finally the quality of the surface finish can be specified in an attempt to reduces stress markings which may lead to system failure during the expansion process as outline earlier.

Description of System

The system outlined in this paper depicts a stage approach to the monobore well program. This system allows an expandable liner to be deployed through an intermediate length casing section and expanded below this section while maintaining the same ID as the intermediate string. The system is connected to the intermediate casing string via a recess profile located at the end of the intermediate string. A top-down expansion method is used to change the casing between its run in state to its post expansion state after it has been deployed to depth.

Method of Deployment

The first stage of the system is to run a special recess shoe at the end of the intermediate casing string in place of the standard casing cement shoe. This recess shoe has a protective ID that prevents cement from contacting the shoe ID and is readily drilled up by standard bits.

The recess liner shoe replaces the standard casing guide shoe that is typically run with liner applications. The shoe is a passive device and function as a standard casing shoe until it is needed. The use of standard float equipment and standard cementing practices is still maintained with the shoe. However, should drilling problems be encountered, the shoe is activated to allow an expandable liner to be deployed. The recess ID of the shoe allows the contingency liner to be expanded into this area, thus preventing any wellbore ID restrictions below the existing liner. In applications were cementing the expanded liner is required a recess shoe with the ability to take annuls returns can be used. This ability to take returns from the annulus region of the expanded liner provides the flow path mechanism for allowing annulus fluid displacement during cementing operations.

The shoes consists of an inner sleeve made out of composite materials which isolates the cement from the shoes recess walls. The composite material is readily drilled out using standard drilling bits. This allows for a post cement shoe track drill out comparable to standard shoes and protects the ID of the recess shoe should the contingency expandable liner need to be deployed.

The expandable liner is deployed in the standard manner as traditional casing with the caveat of the material and connections capable of being expanded and maintaining pressure integrity. In non-cemented applications inserted at the desired locations in the casing string are rubber coated pipe sections which provide annular sealing capability. These rubber elements expand outward with the expanding pipe against the open hole wellbore. Cemented systems use traditional cement as the annulas sealing medium.

Once the complete length of liner has been assembled with an openhole running shoe attached to end, the running/expansion tool is attached to the top of the liner. The system is then run to depth locating in the recess shoe at the end of the intermediate casing string via an indication mechanism.

A retrievable liner running shoe is located at the end of the expandable liner. This shoe allows the expandable liner to be placed in an openhole environment, providing the same benefits of a conventional openhole casing shoe. However, the shoe has a profile located in its ID that engages a retrieval tool located on the end of the liner expansion system/tool. This allows the shoe to be retrieved from the end of the liner after complete expansion via attachment to the running/expansion tool. The retrieval of the shoe leaves the expanded liner with an unobstructed full ID end with no drill out required.

Expansion Method

Once the line has been positioned down hole, the liner is expanded top down via a hydraulic mechanical system. This expansion system is also the same tool used to carry the liner to depth. The pipe is expanded via a taper-shaped circular cone which is moved through the liner to change the liner from its run-in size to its post expansion size. The mechanism that generates the energy to move this cone through the pipe is a hydraulic piston and anchor combination. This system functions by translating the pressure applied to the wellbore drillpipe fluid to mechanical linear force via a downhole piston attached to the expansion cone. The piston-generated force is countered by a hydraulic anchor that is pressure-activated simultaneously with the piston. The anchor secures the top section of the piston to the surrounding casing and thereby provides the reaction force to prevent up hole movement of the drill pipe when the piston strokes the cone down the wellbore expanding the pipe through its stroke length.

The deployment and expansion of the liner system is outlined as follows (See Fig. 5):

• A & B - Run expandable liner to setting depth via running/expansion tool on drill pipe. Setting depth puts the top of the liner inside the special recess shoe located at the end of the intermediate casing string.

• C- Apply pressure to the drill pipe string which activates the hydraulic anchor and activates piston connected to the expansion cone which beings the expansion process.

• D- Once the piston has completely stroked release pressure from the system which deactivates holding anchor and allows tool to move freely in wellbore.

• E - Close piston and reset tool by setting down on drill pipe. Apply pressure to system and repeat expansion cycle.

• Cycle tool until complete liner length has been expanded.

• During last cycle the end of the expansion tool will engage the liner run-in shoe located at the end of the expandable liner. This shoe will become locked to the running/expansion tool and be retrieved to the surface with the tool when expansion is complete.

• F- In applications were cement is desired for annular sealing a conventional cement retainer is placed at the end of the expanded liner and cement pumped through the retainer to the annulus region.

• G- The next section of wellbore can then be drilled utilizing the same size drilling bit as previous hole section.

System Development Testing

The system key components under went initial component testing at the development lab facility which was followed by full system testing at a 500ft deep test well facility. This testing was used to develop and prove out various methods/sizes of material to expand as well as rig site deployment procedures. During this development phase various types and sizes of materials were tested in conjunction with an expandable thread to determine the most efficient design the weighted factors such as: expansion percentages, final system performance strength, expansion forces, and material toughness during deployment.

Following test well development of the system field trials were conducted in “controlled commercial wells.” The “controlled wells” allowed the well to be set up in such a manner that if any problems were encountered during deployment the system the system could be recovered and the well completed conventionally. The purpose of these field trials were to deploy/test commercially viable lengths of expanded material and to further refine rig site processes.

Conclusions

The use of expandable metal technology has the potential to provide alternatives to current well construction technologies. The creation of monobore type well construction could yield not only in technical benefits, but financial benefits as well, by allowing operators to more effectively recover oil and gas deposits. The system outlined in this paper is the first stage of such a well development. As the technology develops, the ability to expand multiple casing strings in the same well without loss of inner diameter will most likely evolve. The use of expandable metal technology is another tool of enabling technology being offered to the oil and gas industry to help provide solutions to delivering production from increasingly challenging hydrocarbon developments.

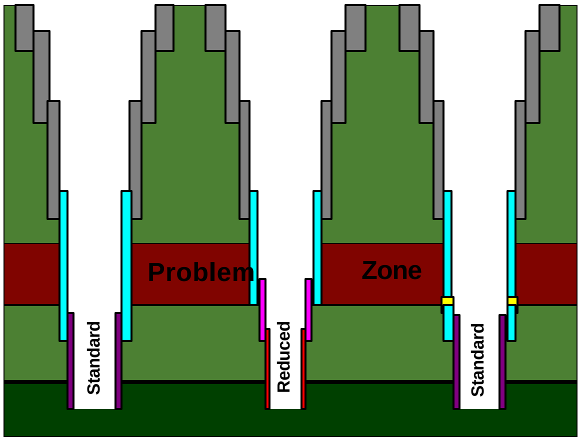

Fig. 1

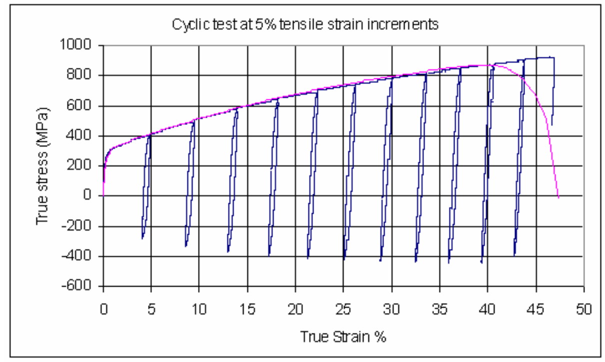

Fig. 3

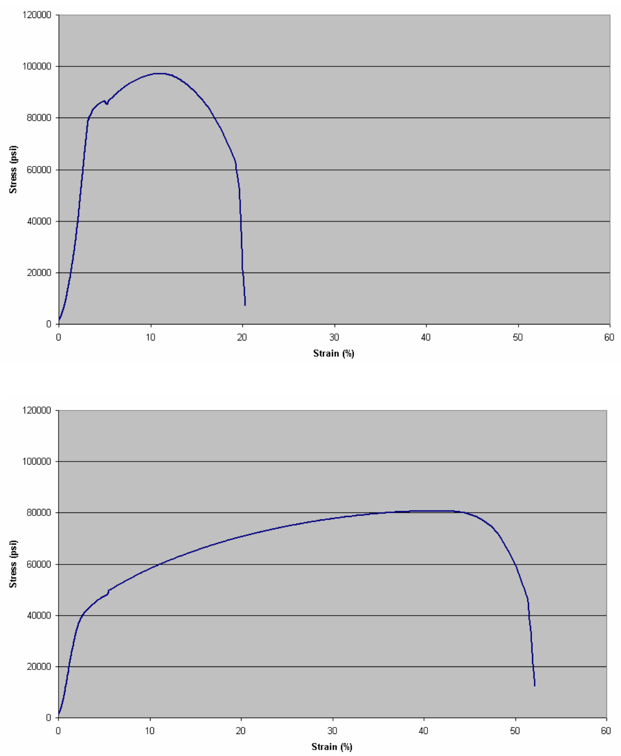

Fig 2

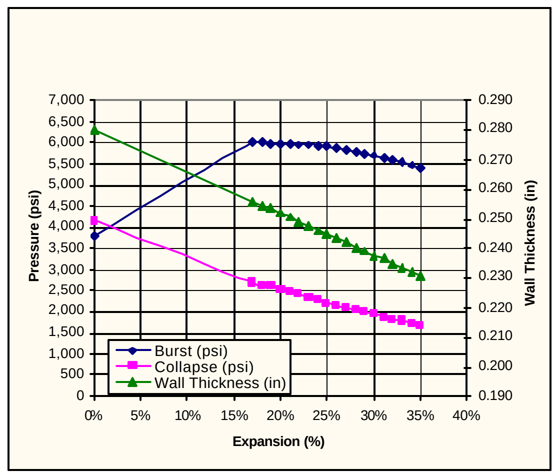

Fig. 4

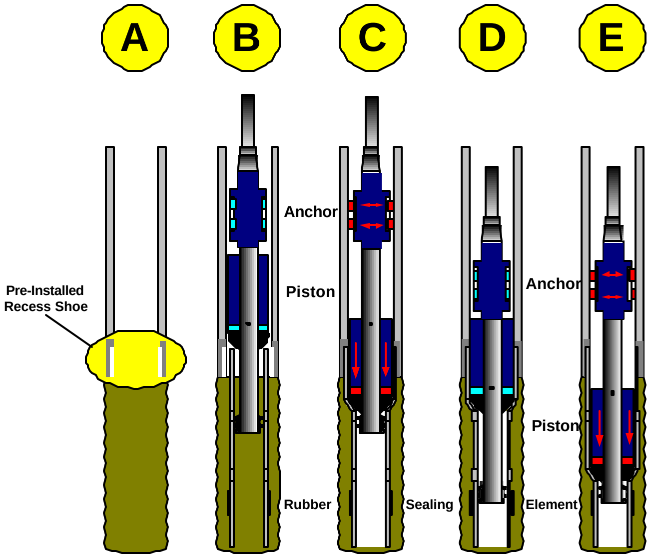
A
B
C
D
E
Pre-Installed
Recess Shoe
Anchor
Piston
Rubber
Sealing
Element
Anchor
Piston

Fig. 5

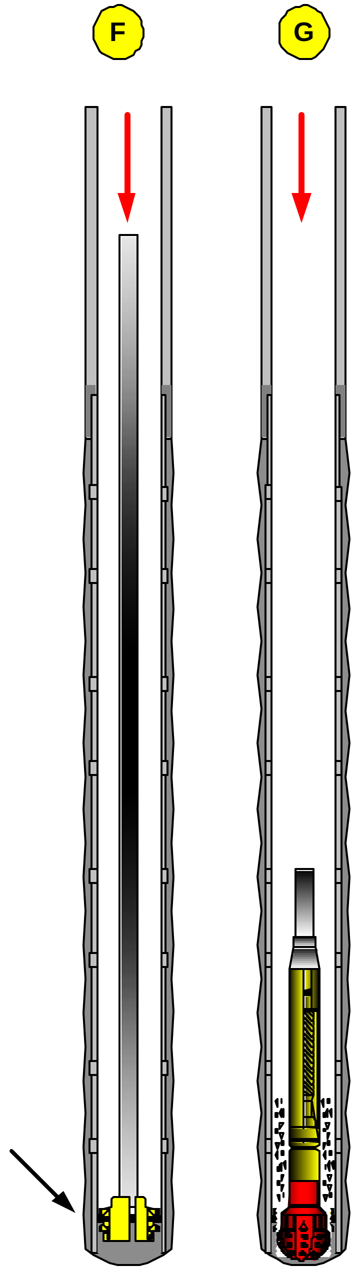
F
G

Fig.6