High Strength Monobore Assemblies With Expanded D:t=12

For The

Drilling Engineering Association, November 13, 2013
Elastic Expansion Technology-DEA Background

- Elastically biased tubular expansion concept first presented as DEA 158
- R&D funding for two applications in 2005 by DOE-NETL MHT and IOC’s
- Designed, built, tested, and deployed 36% same-diameter expansion of solid microhole sized liner application.

- Designed, built, tested, and deployed 50% expansion, 40% open area elastic sandscreen through microhole liner on a same diameter basis.
  - Screen surpasses SIEP, BP specifications
  - Resolves ESS issues

- Technology advancement required successfully connecting tubes with high collapse resistance, achieved 2013.
  - Nominal 20” OD system preparing initial field trials.

- 50 downhole applications identified with sponsors’ assistance.
Presentation Key Points

- Self-expanding tubular technology is simultaneously >10,000psi and single diameter pipe that can extend most any deephole or deepwater hole size, casing point or casing diameter, including the large tophole sections, with massive liners, constructed with very high strength alloys.

- Elastically biased expansion provides responsible properties to expanded collapse strength by use of high yield steels and high wall thickness, approaching 2” in larger diameters.

- The elasticity based expansion process does not suffer traditional reliability or strength limitations.

- Original interest in development is based also on elastic state materials’ remaining expandable after exposure to drilling stresses.

- The elastic expansion approach is opposite the yielded approach in nearly all respects.
  - High properties increase with pipe diameter.
Elastic Expansion Technology Principles

Process Is Fundamental Opposite to Plastic Expansion

Manufacture Expandable Pipe from Elastic Members:

- Form Diametrically Oversized Leaf-Lamination Members
- Assemble & Join Members as an Oversize Spring-Tubular.
- Temporarily Reduce & Secure Diameter
- RIH as D:t=8, Partially Release Elastic Energy
- Elastically Recover Device Past Confining Diameter
  - Elimination of Bauschinger effects, no-shrinkage
- Seal Wellbore with Residual Outward Spring Energy
  - Constant, non-hysteretic contact, self-hanging and self-sealing
Elastic Recovery of High Strength Laminated Members

\[ E = \text{Modulus of Elasticity} \]
\[ \sigma_y = \text{Yield Stress} \]
\[ D_{\text{comp}} = \text{Compressed Diameter} \]
\[ D_{\text{exp}} = \text{Expanded (Free State) Diameter} \]
\[ t = \text{Thickness} \]

\[
D_{\text{exp}} = \frac{D_{\text{comp}}}{1 - \frac{D_{\text{comp}} \sigma_y}{Et}}
\]

\[
D_{\text{comp}} = \frac{D_{\text{exp}}}{1 + \frac{D_{\text{exp}} \sigma_y}{Et}}
\]

\[
t = \frac{D_{\text{exp}} D_{\text{comp}} \sigma_y}{E (D_{\text{exp}} - D_{\text{comp}})}
\]
Operation and Control of Diametric Changes

Reduction of Oversized Assembly

- Diametric reduction of oversized as-formed assembly to RIH diameter can require in excess of one million pounds per foot.

- Loading at OD of compressed-RIH state averages 40-psi.

Expanded Recovery Downhole

- Expansion initiation and opening forces are completely tunable design parameters, not reliant on yielding tube body.
  - Hundreds-psi to tens-thousands-psi

- Continuous external preload and annular sealing sleeve restrains initial release through final set.
New technology (left) allows 2.4X and more increase in wall thickness over conventional expanded pipe (right cross-section). DTS high wall-thickness abilities provide basis for >900% increase in expanded collapse resistance.
Elastic System Collapse Properties


- V150 material with D:t 12.5 at same collapse standards = 16,200psi – 23,000psi.
  - Range is discounted, with increased tube roundness not recognized.

- Elastic technology retains 70% - 90% of standard pipe properties.

- Burst and collapse are ~ equal for technology.

- Integrity results from the accumulation of high strength materials, thick-wall structure, retained expansion force, and leaf surface bonding details.

- Technology properties are adequate even for large diameter, non-cemented openhole applications >10,000’.

7-5/8” Expanded D:t = 13.0.
Preliminary Collapse Results = 10,400psi.
- Lowest case collapse & burst properties -- surface area vs. shear strength for various unjoined layer quantities in early 6,000psi collapse design. Shear strength requirements are reduced according to increases in the number of device layers (Source SwRI).

- Structural joining of member edges >halves simple shear strength requirements.

- Members’ surface friction grows exponentially \( P_2 = P_1 e^{\mu \theta} \) according to layer quantity; expansive friction effects generated internally eventually replicate 100% of simple bonding curves, but not reliably enough alone.

- Anti-collapse direction surface engagement and bonding features supplement joined edges & friction effects.

- 70% - 90% of fundamental tube collapse properties are realized, depending on technology configuration.
Internal Pressure Sealing

- Internal pressure seal is by interference to soft-middle strength metal coatings and non-metallic coatings, as applied to member surfaces.

- To 90% of conventional radial mechanical properties are also produced as a further function of coated surfaces.
Annular Self-Seal

- Continuous length preload sleeve provides contact, fluid barrier, and dampened confinement effects directly against formation or cement.

- Residual outward bias in the assembly produces 3X – 7X sealing properties to expansive input force.

- Large pipe expansion ratio allows for both adequate RIH clearance and high thickness sleeves.
  - .500” and greater sleeve thickness capable for larger pipe diameters.
Connecting High Collapse Expandable Tubes

- CFEX© connection designs are unpublished.

- Design emphasis is on collapse performance, where the expansion process causes creation of resistant structures.
  - Collapse based design is 4-D in nature.

- System provides conventional casing ratings and handling approaches, but with tensile generally limited <10,000’.

- Use of substantial strength materials and elimination of Bauschinger shrinkage allows realization of high-end connecting properties, even at 40% expansion.

- System utilizes premium connecting details which claim retention to 100% of tube properties.

- Elastic state system disperses collapse stresses, eliminates shear planes, and is internally supported by the massive wall.

- >90% of tube collapse properties are maintained.
Hydraulic Integrity for Elastic Connecting

- As a multiple layer-component device, normal connector vulnerability to fluid contamination is able to be isolated.

- Connecting mechanism is isolated by long leak path at ID and continuous preload sleeve about the OD.

- Non-shrinkage of material also maintains constant, elastic interference of connecting elements.

- Use of substantial material properties are inherently more resistant to deflections by fluid stress.

- Coordinated system lamination provides natural tendency to flex rather than yield at high load.
Conducted across various development phases for sizes ranging 4” – 20” OD.

- Full 8:1 length mechanical testing, 2007.
- Tubes and elastic screen originally demonstrated in ground 2007 as single diameter installation.
- Connector details tested at full L:d showing >90% of tube properties.
- Detailed short sample length technical performance and manufacturing process testing for 7” and 20” conducted 2012-2013 covering 40 items.
- Full L:d and functionality laboratory testing scheduled for 2014.
- Expansion to date carried out as both mechanical and hydraulic processes.
Scab Liner Field Trial – Bit Diameter Maintenance

A. Problem section diameter is opened.

B. Compressed assembly is passed through existing borehole or casing.

C. Elastic assembly is set directly to opened section formation or is cemented.

D. Drilling continues with the original bit diameter. Repeat process indefinitely.

❖ 20” OD Self-sealed, uncemented LC patch field trial to be performed in 2015.