Finite Element Analysis of Perforation Patterns in Production Liners Exposed to Subsidence

7 5/8” 39# Q-125 Perforated Section Analysis Compaction Study

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AUTHORS: Greg Bailey, Mark Brinsden, Xin Long – Shell
Presented by: Mark Brinsden - Shell
MATERIALS

Cement – Isotropic Elastic
Density - .083#/in³
Modulus – 4,000,000 psi
Poisson’s Ratio - .2

Formation – Isotropic Elastic
Density - .096#/in³
Modulus – 1,450,000 psi
Poisson’s Ratio - .2

Pipe – Q125 – Isotropic Elastic/Plastic
Density - .287#/in³
Modulus – 30,000,000 psi
Poisson’s Ratio - .29
Pipe – 7.625” x 6.625” – Red Region
Cement – 8.5” x 7.625” – Green Region
Formation (Sandstone) – 45.75” x 8.5” – Grey Region
Length = 14”
Strain = 6% = .84”
Cross sectional area of pipe = 11.2 in²
SMYS = 125,000 psi
Axial Force to Yield = 1399 kips
Bond Strength of Cement = 250 psi
Bond Area to Carry Yield Load = 250” = 20.83’ = 
(1398990/(pi*7.625*250)
Shear Stress on 14” Model = 4172 psi – Due to the short length
of the model, the shear stresses at the interface will be artificially
high
Perfect Bond Modelled
Perforation size = .88”
15 SPF
Phase 135 degrees
Helix 5.625 turns per foot
Perforation Depth/Length = 7.625”
Boundary Conditions in Cylindrical Coordinates Applied Solely to the Formation

Axial Constraint – $Z = 0$
Radial Constraint – $R = 0$
Displacement Load – $Z = .84”$
476764 Elements
Shear Stresses at Pipe to Cement Bond Interfaces

The conclusion is that bond strength is exceeded in regions where the shear stress exceeds 4450 psi (~4172+250). It is feasible that the cement in the nonperforated section could transfer the compressive load from the formation into the pipe via the bond.
Shear Stresses at the Bond Interface at the outer diameter of the cement sheath are similar, so the bond status at that interface could be questioned.
The conclusion is that the cement exceeds its compressive strength (~4500 psi) rather early in the process. How the cement behaves, i.e. self healing, under the high hydrostatic loads between the pipe and formation requires further study.
Ovalization of Perforations

Affect on:
Hydraulic performance?
Sand Production?
What if Bond is Broken Between Cement & Pipe?

Pipe – 7.625” x 6.625” – Grey Region
Formation (Sandstone) – 7.625” x 25.5” – Green Region
Length = 14”
Strain = 6% = .84”
SMYS = 125,000 psi
Top Surface Free to Rotate
No Bond or Friction at the Interface Modelled – Multi-Body Contact
Perforation size, Pipe Only = .88”
15 SPF
Phase 135 degrees
Helix 5.625 turns per foot
Perforation Depth/Length = 7.625”
Axial Constraint – $Z = 0$
Radial Constraint – $R = 0$
Displacement Load – $Z = 0.84”$
Note Tendency for Pipe to Rotate Relative to the Formation

Multi-Physics Approach Warranted?
Mechanical analysis at high strain rates
CFD of deflected geometries
Erosion studies with velocity profiles
Life estimates at regions of potential wash out
QUESTIONS? THANK YOU

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