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Charles Pope

Stop, Drop And Circulate, An Engineered Approach To Coiled Tubing Intervention in Horizontal Wells

#SPEDL
Stop, Drop And Circulate
An Engineered Approach To Coiled Tubing Intervention in Horizontal Wells

Charles Pope
Complete Shale
Agenda

• Global coiled tubing usage
• Problems with historical practices
• Results from a few case histories
• Take away
Where and how coiled tubing is used
Coiled Tubing Intervention

Initial Completion:
• Well Prep
• Perforating
• After Frac Drillouts
• Coiled Tubing Fracs

Cleanouts Prior to:
• Acid Stimulation
• Chemical Treatments

Also used for:
• Logging
• Fishing
• P&A
Typical Wellbore Configuration

- Coiled Tubing
- BHA
- Bit
- Bottom Hole Assembly
- Composite Frac Plug
- Plug Debris
- Sand and Composite Material
Annual Horizontal Wells Drilled

Sources: Rystad Energy, 2017; Baker Hughes
Active Coiled Tubing Units

1472 Active Units

- Russia/CIS: 330
- North America: 324
- Europe/Africa: 122
- Latin America: 211
- Middle East: 218
- Far East: 267
Horizontal Wells Drive Larger Pipe

- 2014: 66% 2" Coil
- 2015: 51% 2" Coil
- 2016: 47% 2" Coil
- 2017: 37% 2" Coil

- 2014: 32% 2 3/8" Coil
- 2015: 45% 2 3/8" Coil
- 2016: 41% 2 3/8" Coil
- 2017: 54% 2 3/8" Coil

- 2014: 2% 2 5/8" Coil
- 2015: 4% 2 5/8" Coil
- 2016: 12% 2 5/8" Coil
- 2017: 9% 2 5/8" Coil

NOV/Quality Tubing 2017
Why is this Important?

Spent $60MM

28% of spend

Top 10 drillouts cost $17MM

Cost overruns on 30% of wells

Average costs $250k

Stuck pipe: 1 well in 16

2015
Historical Practices

- Very little engineering support
- Applied vertical well techniques
- Short trips
- Gel sweeps
- No digital data gathered
Short Trips

- Short trip is pulling out of the hole
- Usually into the vertical
- Uses the Bottom Hole Assembly to clean the hole
How Common is Stuck Pipe?

• From 2001 to 2010: stuck pipe incidents increased 43%. (Burgos, SPE 163914)

• 2012 in BC: stuck ~0.25 hrs per plug. (Lyndsey, SPE 178644-MS)

• From 2013 to 2015: 600 interventions, stuck 14 hrs per well. (Pope, SPE 187337-MS)

“An ounce of prevention is worth a pound of cure.” Benjamin Franklin
Causes of Stuck Pipe

- Sand cleanouts represent the biggest hazard.
- Routine interventions account for 77%.
Where do we get Stuck?

- 26 confirmed events
- 22 short trips
- 2 when picking up off bottom
- No stuck events in curve
- 85% of time stuck pipe is related to the short trip

Location of stuck pipe event normalized by lateral length
Effect of Short Trips on Time

Example: 16,500 ft 30 Plugs
Sweeps

- 10 bbl sweep after drilling every plug
- 33% of wellbore volume is sweep material
Velocity and Viscosity

Model Parameters:
- 5 ½” Casing
- 2” Coiled Tubing
- 3 BPM
- 175 fpm
- 108 cp

\[ \mu_a = 21 \text{ cp} \]

\[ \mu_a = 370 \text{ cp} \]

Modified from Hutchings (2013) and Chin (2001)
Lift and Drag Forces

Modified from Farajzadeh, 2004

\[ F_L = \frac{0.761 \tau_w^{1.5} d_p^3 \rho^{0.5}}{\mu} \]

\[ F_d = 3\pi \mu d_p \nu_p \]
Investigate Laboratory Results

• Observe the fluid-debris interaction
• Are basic assumptions about hole cleaning valid?
• Many service companies have flow loops
• Several Universities have horizontal flow loop consortiums
Debris Movement
Viscous Fluid

200 Funnel vis, 3 BPM, 260 fpm

Emerald Surf
Debris Movement in Slickwater

27 Funnel vis, 3 BPM, 260 fpm

Emerald Surf 2013
Annular Velocity and Reynolds Number

\[ Re = \frac{928 \rho v (d_2 - d_1)}{60 \mu} \]

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<th>AV, fpm</th>
<th>Funnel Vis</th>
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Sweep Displaced by Slickwater
British Columbia Case History

- Wiper Trip Matrix
- Stuck pipe: every well
- Fluid Costs > $40k
- Re-entrainment of solids a function of Reynolds number

SPE 178644-MS/URTeC:2155463 (2015)
• Single Trip Cleanouts (some wiper trips)
• Gel Sweeps minimized
• Chemical usage down 95%
• Reynolds number >20,000
Eagle Ford Shale Case History

- Single Trip Drillouts
- Non-Viscous Fluids
- ~2x plug recovery

Gel elimination trial

<table>
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<th>Phase II</th>
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</table>

SPE179070–MS (2016)
Woodford Case History

- 33 similar wells
- 2” Coiled Tubing, 5 ½” Casing
- 5000 ft laterals
- 30 or more composite frac plugs
- 1 coiled tubing vendor
- 1 chemical vendor
- No short trips
- No gel sweeps
Debris at Surface

- Weigh Debris
- Record Time
- Plot Data
Debris Monitoring

- Better hole cleaning
  - Higher AV’s up to 300 fpm
  - Higher Re up to 50,000
- BHA is not bringing up additional debris
Sand Monitoring

- Acoustic meters provide continuous sand measurement
- Good hole cleaning
  - Linear response
- Curve flattens as a BHA nears the surface
Woodford Results

- No stuck pipe
- Costs decreased 50%
- Time on location improved 50%

SPE 187337–MS (2017)
Location of Plug Debris

AV=200 fpm
Slickwater: 1/5 of AV
Sweep: 1/20 of AV

BHA collides with plug debris
BHA travels in debris field to surface
WHAT HAPPENS TO A GEL SWEEP WHEN IT IS PUMPED DOWNHOLE?
What happens to a gel sweep downhole?

Commercial Cementing Simulator
2" Coil in 5 ½" casing
5000 ft lateral
20 bbl Sweep
Initial viscosity 150 cp

Final Viscosity
~10 cp

Sweep elongates to 2500 ft
Mixing with wellbore fluids
Travels over top of debris

Flow Profile
Polymers Breakdown

- Mechanical forces
- Pumps, motors, bit jets, etc.
- Chemical Reactions
  - O2
- Fluid loses 65-85% of original viscosity
OTHER CRITICAL ISSUES
Low Bottomhole Pressure

• Information Gap
  – Bottomhole pressure
  – Required N2 injection rate
  – Engineers do not recommend N2 injection rates
• Field is expected to just know the correct N2 rate
  – Results in over injection
  – Drives costs higher
• Wait too long to start N2
• Several commercial models are available
• Use gas lift curves to estimate circulation bottomhole pressure
Friction Reducers

• Reduces the pumping pressure
• Polyacrylamide is most common
• Does not extend reach
• More is not better
  – Lab based loading
• Will not prevent stuck pipe
• Check effectiveness
  – Pump pressure before and after
  – Discontinue if not effective
Metal to Metal Friction Reducers

- Often called “Pipe on Pipe” (POP)
- Only works where there is:
  - metal to POP to metal contact
- Usually batch treated
- Usually applied too late
- Will not prevent stuck pipe
- Check effectiveness
  - Weight check before and after
  - Discontinue if not effective
Warning Signs of Stuck Pipe

- Reduced or lost returns
- Abnormal weight check
- Erratic pump pressure/motor stalls
- Loss of plug debris being collected in plug catcher
- Reduction in produced sand at the surface
Preventing Stuck Pipe

What to do:

- Stop, Drop and Circulate
  - Do not continue to pull into tight spot
- Circulate 1 hole volume
- Perform a weight check
- Repeat until surface weight returns to trend

Torque and Drag (TAD) Plot

Pulling Tight
Increase Engineering Involvement

- Create TAD Roadmap
- Model Cleanout
- Plan Fluid System
- Data Requirements

Procedure
Take Away

An Engineering Approach

• Use bit/BHA to drillout debris
• Use fluid to clean the hole
• Improved hole cleaning
  – High annular velocities
  – High Reynolds numbers
• Electronically record all the data
• Learn from the data
• Observe warning signs of getting stuck
  – Stop, Drop and Circulate
Thank You

- Complete Shale
- Drillout Group
- Industry Partners
- My Family
- SPE Foundation
Thank You!

Questions?

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