Rheology : A Key Parameter for Plug Milling Efficiency

Saad Hamid
Agenda

• Completion Practices in North America
• Coiled Tubing Milling & Cleanouts
  – Challenges
  – Current Practices
• Role of Fluid Rheology
• Case Histories
• Conclusions
• Questions
Completion Practices

- **Composite Bridge Plugs**
  - Completion and stimulation flexibility
  - Cemented casing/liner
  - Verified method
  - Perforating and milling cost
  - Longer stimulation time

- **Multistage Fracture Sleeve**
  - Multiple stages
  - Continuous stimulation
  - No cemented liner required
  - Restricted wellbore access for re-frac
  - Completion intervals pre-planned
The Need To Mill

- Bridge plugs MUST be removed to start production
- Frac Sleeves may stay in hole but balls must flow back
- Frac balls wedge into seats – can take as much as 1000 psi differential to remove
- Each seat acts as a down hole choke – not significant if only 3-5 stages...
- ... but what if there are 40 stages?
- Can cause significant production impairment (SPE 138322)
Intervention Challenges

- Long Laterals with TD exceeding 5000m.
- Complex well trajectories.
- Sour environment.
- HPHT.
- Ever increasing number of stages.
- Plug / seat / ball materials.
Coiled Tubing Milling

Objectives
• Reach the desired depth
• Mill all plugs
• Circulate out all cuttings to surface
• Leave a clean hole

Challenges
• Lock up
• Insufficient WOB
• Variable cuttings size
• Sand, Metal, rubber etc.
• Higher Pump Rates
• Higher HP requirement
• Coiled Tubing Size
• Coiled Tubing Fatigue...
Current Practices

- Pump FR to reduce friction pressure.
- Pump gel sweeps to carry cuttings.
- Perform wiper trips every 2-4 plugs milled to transport solids to vertical.
- Stuck Pipes
- Insufficient hole cleaning.
- Subsequent venturi runs.
Are we REALLY doing it right?

• Current practices came from vertical wells and drilling rig techniques
• In horizontals, solids settle out no matter WHAT is pumped
• Higher pump rates and pipe rotation allow rigs to re-entrain solids
• CT does not rotate, need turbulence to re-entrain solids:
  higher rates, lower viscosities or wiper trips
Understanding Solids Transportation

**Vertical Section**
- Increased viscosity helps
- Laminar flow acceptable

In the vertical, flow is parallel to gravity so particles are continuously re-entrained.

**Horizontal Section**
- Increased viscosity hurts
- Laminar flow drops solids to low side of liner
- High velocity and low viscosity allows turbulence
  
  Particles settle out quickly without turbulence

*Water at 500 lpm erodes the dune at 2 m/min.*
*Gel does NOTHING!*

*Dunes are created by improper fluid rheology*
Optimizing Rheology

**Water**
- Low viscosity fluid ( ~1 cP)

**Friction Reducers**
- Long chain polymers
- Low viscosity (~2-5 cP)
- Designed to suppress turbulence at the tubing wall only

**Gels**
- Guar based polymer linear gel
- High viscosity (~20-60 cP)
- Designed to keep solids entrained, difficult to pump into the turbulent flow regime
- Degrades with temperature
Rheology Control System

- Proprietary System comprising of:
  - Patented Inline Mixers
  - Patented Dual Flow Loops
  - Chemicals
  - Real time monitoring and optimization of fluid rheology.
Rheology Control System

- Addresses major concerns about coiled tubing operations
- Consistency in pressure control
- Optimization of chemical usage
- Optimization of Rheological metrics for debris removal
- Adaptability and Flexibility without compromising accuracy
- Trained Fluid Engineers on site.
NO GEL USED
Case History 1

- TD>5200mKB; TD/TVD>2
- 139.7mm Casing w/20 Plugs
- 60.3mm CT
- 73mm BHA
- 2 Runs
- As little as 29mins spent per plug
Case History 2

- TD>5100mKB; TD/TVD>2
- 139.7mm Casing w/21 Plugs
- 60.3mm CT
- 73mm BHA
- 2 Runs
- As little as 31mins per plug
- Motor failure after Plug 18
And More...

- >60% reduction in cost per plug
- 50-70% reduction in drill time per plug
- 50-70% reduction in chemical usage
- Improved solids transportation
Conclusion

Conventional vs Optimized Plug Milling

DEPTH (m)

0 1000 2000 3000 4000 5000 6000

TIME (hrs)

0 10 20 30 40 50 60 70 80

Intervention & Coiled Tubing Association
Summary

OPTIMIZE  Rheology

PROFITS

Costs
THANK YOU
Case History

- TD>5100mKB; TD/TVD>2
- 139.7mm Casing w/20 Plugs
- 60.3mm CT
- 88.9mm BHA
- 4 Runs
- Avg. 63mins spent per plug
- BD vs. Ported Sub.