Optimising Hydraulic Energy to Dramatically Improve Lateral Reach
What Affects Reach?

- Build angle
- Size of completion
- CT size
- Drag
  - Mechanical
  - Fluid
- Debris in well
- BHA size
- End load
What Can We Control?

• CT size
• End load
• Buoyancy
• Drag
Helical Buckling

- Neutral Point
- Sine Wave Buckling
- Unsupported Section
- Helical Buckling
- Spiral Pitch
2” CT Simulated Plug Mill out

5 ½” Casing, (4.892 ID)
KOP = 6,800 ft
Hz Length = 10,000 ft
Plugs = 8
Fric. Coefficient = 0.24

Depth = 7,730 ft
WOB = 5,200 lbs
2” CT Simulated Plug Mill out

5 ½” Casing, (4.892 ID)
KOP = 6,800 ft
Hz Length = 10,000 ft
Plugs = 8
Fric. Coefficient = 0.24

Depth = 9,930 ft
WOB = 2,900 lbs
2” CT Simulated Plug Mill out

5 ½” Casing, (4.892 ID)
KOP = 6,800 ft
Hz Length = 10,000 ft
Plugs = 8
Fric. Coefficient = 0.24

Depth = 12,145 ft
WOB = 930 lbs
2” CT Simulated Plug Mill out

5 ½” Casing, (4.892 ID)
KOP = 6,800 ft
Hz Length = 10,000 ft
Plugs = 8
Fric. Coefficient = 0.24

Max Depth (200 lbs WOB) = 13,245 ft
Max Mill Depth (1000 lbs WOB) = 12,065 ft

Depth = 13,245 ft
WOB = 200 lbs
Solutions

- Larger CT
  - 2-3/8” CT or greater
2-3/8” CT Limitations

• Higher cost: 30% more than conventional 2”
• Length and reel capacity limitations
• Travel limitations (DOT, special permits)
• Equipment availability
• Less fatigue life
5 ½” Casing, (4.892 ID)
KOP = 6,800 ft
Hz Length = 10,000 ft
Plugs = 8
Fric. Coefficient = 0.24

2” w/ PDM
Max Depth: Fric. Lock = 13,565 ft, 1,000 lb WOB = 12,065 ft

2-3/8” w/ PDM
Max Depth: Fric. Lock = 15,140 ft, 1,000 lb WOB = 13,870 ft
Solutions

• Metal to metal lubricants
  – Fatty acid esters
  – Fatty alcohols
  – Polymer beads
Metal on Metal Lubricants

- 15-25% friction reduction
- Can be used in most situations
- Only pumped if needed
- Cost varies depending on volume used
2” Simulated Plug Mill out w/ Lubricant

5 ½” Casing, (4.892 ID)
KOP = 6,800 ft
Hz Length = 10,000 ft
Plugs = 8
Fric. Coefficient = 0.24

2” w/ PDM
Max Depth: Fric. Lock = 13,565 ft, 1,000 lb WOB = 12,065 ft
2” w/ PDM Max Depth Lubricant: Fric. Lock = 14,935 ft, 1,000 lb WOB = 13,200 ft
Solutions

• Mechanical devices such as tractors
Tractors

- Give large pulling force
- Increase risk of getting stuck
- Long tool length, longer lubricator/larger crane
- Less reliable in sand environments
- Limited use in open hole completions
- Complex tools with lots of moving parts
2” CT Simulated Plug Mill out w/ Tractor

5 ½” Casing, (4.892 ID)
KOP = 6,800 ft
Hz Length = 10,000 ft
Plugs = 8
Fric. Coefficient = 0.24

2” w/ PDM
Max Depth: Fric. Lock = 13,565 ft, 1,000 lb WOB = 12,065 ft

2” w/ PDM Max Depth w/ tractor: Fric. Lock = 18,266 ft, 1,000 lb WOB = 15,038 ft
Solution

- Rotating valve water hammer tools
- Motor operates a rotating valve
- Valve partially interrupts pumped fluid
- Interruptions create water hammer
- Creates sinusoidal pressure wave
- Frequency depends on flow rate
Sinusoidal Wave from Rotating Valve
2” Simulated Plug Mill out w/Rotating Valve water Hammer Tool

5 ½” Casing, (4.892 ID)
KOP = 6,800 ft
Hz Length = 10,000 ft
Plugs = 8
Fric. Coefficient = 0.24

2” w/ PDM Max Depth: Fric. Lock = 13,565 ft, 1,000 lb WOB = 12,065 ft
2” w/ PDM Max Depth w/Rotating Valve Water Hammer Tool: Fric. Lock = 16,372 ft, 1,000 lb WOB = 14,465 ft
Solutions

• A new tool design was needed
New Tool

• Extensive computer flow modelling was required
• Optimum frequency and wave shape were determined to achieve maximum benefit
• Best results are with a square wave with a 50% open to 50% closed ratio
• Exhaustive laboratory testing was done
• Prototypes were built and tested
Typical Lab Test Setup
Solutions

• New Square Wave Water Hammer Extended Reach Tool
Square Wave Tool

• A high power water hammer tool
  – Produces square wave pressure pulses (<10 Hz)
  – Frequency is independent of flow rate
  – 50% open to 50% closed ratio
  – Tunable to accept flows from 1 – 5 bpm

• Efficient
  – Can be tuned to give only the required water hammer to reach the target depth regardless of the total flow rate being pumped

• Mechanically simple
  – 1 moving part (piston)
  – Does not have limitations of down hole motors
    • Gas swelling, temp limits, chem. compatibility, etc

• Compatible with typical CT BHAs
  – Jetting
  – Clean outs
  – Milling
Tool Operation

• Piston opens and closes valve to interrupt flow of treatment fluids
• Piston is controlled by a fluidic switch
  – Coanda effect
• Large forces can be created at the end of the coil to pull the coil into the well
Fluidic switch

Snapshot simulation of jet switching

Drive flow to piston

Return flow from piston

Velocity (m/s)

From tool piston

Vent

Control jet flow

5 – 10% of main flow
2” CT Simulated Plug Mill out w/Square Wave Water Hammer Tool

5 ½” Casing, (4.892 ID)
KOP = 6,800 ft
Hz Length = 10,000 ft
Plugs = 8
Fric. Coefficient = 0.24

2” w/ PDM Max Depth: Fric. Lock = 13,565 ft, 1,000 lb WOB = 12,065 ft
2” w/ PDM Max Depth w/Square Wave Water Hammer Tool: Fric. Lock = 17,253 ft, 1,000 lb WOB = 14,957 ft
Reach Simulation Summary

- 2" w/Square Wave Water Hammer Tool & Lubricant
- 2" w/Square Wave Water Hammer Tool
- 2" w/ Wheeled Tractor
- 2" w/Rotating Valve Water Hammer Tool
- 2-3/8" w/ Lubricant
- 2" w/ Lubricant
- 2-3/8" w/ PDM
- 2" w/ PDM

Max Depth to Friction Lock

6000 8000 10000 12000 14000 16000 18000
Milling Field Case

- Barnett Shale Area
- 5-1/2", 17# Casing, 14,305 ft
- BHP = 4,000 psi
- KOP 6,800 ft (7,000 ft Hz section)
- 17 plugs
- 2” CT
- Work over fluid: recycled fresh water
- 3 1/2 Motor
- Pre Job computer simulation indicated less than 1,000 lbs WOB at 12,800 ft w/ lubricant
Completion Profile

3-D Plot Of Well Profile

TD = 14,305’
TVD = 7,687’
KOP = 6,800’
Max Deviation = 91.45
90 deg @ = 8,470’
BHA Configuration

- 2” CT end connector
- 2-7/8” Check Valve
- 2-7/8” Disconnect
- X-over (PAC to Stub ACME)
- 2-7/8” Downhole filter
- 2-7/8” Square Wave Water Hammer Tool
- X-over (Stub ACME to PAC)
- 3-1/2” Positive displacement motor
- 4-5/8” 5 bladed junk mill
Field Case Milling Comparison

2” CT no Extended Reach Tool

- Total plugs = 13
- Avg. active milling time plugs 1-9 = 38 mins
- Avg. active milling time plugs 10-13 = 89 mins
- Avg. pick ups = 3
- Max depth = 12,956 ft
- Lubricant utilized
- 4 ½” Tri-cone

2” CT w/New Water Hammer Tool

- Total plugs = 4
- Avg. active milling time plugs 14-17 = 16 mins
- Avg. pick ups = 0
- Max depth = PBTD
- No lubricant utilized
- 4-5/8” 5 bladed junk mill
Field Case Comparison

2” Actual Comparison

Depth (ft)

Weight (lbs)

[Graph showing weight comparison between Weight No Tool and Weight W/ Tool]
2” CT Field mill out w/New Water Hammer Tool

Plugs 14-17 were milled using the 2-7/8” New Water Hammer tool.
Square Wave Tool Summary

• Extended reach / weight on bit applications
  – Water hammer creates vibrations along length of CT, decreasing friction
  – Water hammer force is adjustable
  – Wide range of flow rates allowed
  – Cost effective over utilizing larger CT

• Field results
  – Square wave water hammer tool improved milling performance and extended reach
  – Weight on bit better than larger CT
Questions?