“Slickline Fatigue Tracking Software Delivers Economic Benefits”

November 14, 2010
ICoTA Round Table
Calgary, AB

Ed Smalley
Today’s Highlights

• Drivers for New Slickline Technology
• New Technology to Monitor SL Fatigue Life
  – Slickline fatigue model development
  – Corrosion life reduction
• Slickline Inspection
• Example Results
Why Focus on Slickline Fatigue Life?

- Cost, Safety, and Expand Market

**Fatigue Life Monitoring Goals**
- Extend Life / Reduce SL Expenditures
- Improved Safety (SL failures @ surface)
- Reduce Downtime / Fishing Operations
- Increased Customer Confidence in SL Operations
Causes of Slickline Failures

- Mechanical Damage
  - Abrasion, severe bending (kinking)

- Corrosion
  - Rust, acid, H₂S, CO₂

- Fatigue Damage
  - Sheave wheel, overpull

Failure Causes can be Interrelated
- Example: Cracks caused by corrosion can exacerbate fatigue damage

Technology to Quantify both Corrosion & Fatigue Life
Slickline Data Acquisition & Fatigue

• **Data Acquisition System**
  – Acquires depth and weight channels
  – Display & record data during field operation

• **Calculates:**
  – Fatigue damage caused by SL movement/tension

• **Displays:**
  – % Fatigue Life Used vs. length of SL
  – Slickline history (cuts, re-spooling events, etc.)
SL Fatigue Model Development
(Fatigue vs. Crack Propagation)

• Fatigue Damage
  – Damage (bending) accumulates until crack initiation

• Crack Propagation (following crack initiation)
  – Repeated bending causes crack propagation until a failure (fracture) occurs

• CT Fatigue – includes only crack initiation
• DP Fatigue – usually includes only crack propagation
• Slickline Fatigue – includes effects of both
Large Test Machine
(SL Fatigue Model Development)

Air Piston (tension)
Large Test Machine
(16” and 19” Sheave Diameters)
Large Test Machine
(Spilt-Drum Used for Testing)
Plastic Fatigue from Bending Events  
(Bending Strain *Inversely* Proportional to Sheave Size)

Bending Diameter to Initiate Yielding:

\[ D_y = \frac{dE}{\sigma_y} \]

<table>
<thead>
<tr>
<th>d (in.)</th>
<th>Dy (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.092</td>
<td>19.7</td>
</tr>
<tr>
<td>0.108</td>
<td>23.1</td>
</tr>
<tr>
<td>0.125</td>
<td>26.8</td>
</tr>
<tr>
<td>0.140</td>
<td>30.0</td>
</tr>
</tbody>
</table>

Where:
- \( D_y \) = Bending diameter at which yielding begins
- \( d \) = Diameter of slickline
- \( E \) = Modulus of elasticity (30 \( \times \) 10\(^{-6}\))
- \( \sigma_y \) = cyclic yield stress (~140k PSI typical, varies by material)
Strains from a Type 1 SL Rigup
(SL Fatigue Model Development)

- Sp = power sheave
- Sl = lower sheave
- Su = upper sheave
Strains from a Type 2 SL Rigups
(SL Fatigue Model Development)

- Sd1 = depth sheave 1
Strains from a Type 3 SL Rigups
(SL Fatigue Model Development)

- Sd2 = depth sheave 2
Model Results / Tension = 0
(SL Fatigue Model Development)
Model Results / Tension = 2,000 lbs
(SL Fatigue Model Development)
Corrosion / Tracked Fatigue De-Rating  
(Portable Slickline Fatigue Tester)

- Portable SL Fatigue Test Machine  
  - Wellsite use

- Rapid Testing of Short SL Samples  
  - Rotation of SL sample imparts bending strain  
  - Repeatable results

- Determine Life Reduction Due to Corrosion  
  - From tests of actual SL being ran in the field
Corrosion Life Reduction

- **Maximum Corrosion @ Downhole End:**
  - Hottest corrosive wellbore fluids
  - Longest period of time in well
  - Exposure to atmosphere when on drum

- **Corrosion Testing**
  - Samples taken from downhole end during life of SL
  - Test samples in portable tester
  - Compare test results to SL fatigue model
  - If worse, add a corrosion factor to fatigue results
Portable Slickline Tester
(Corrosion De-rating & Maximum Remaining Fatigue Life)

- Records Revolutions to Failure
  - Rotation of SL imparts bending events
  - Convert revolutions to fatigue life

- Sample length = 34 cm

- Multiple Sheave Sizes
  - 30-61 cm (12-24 in)
Sheave Size Adjustment

(Portable Slickline Tester)

Adjustable Tailstock Position to Match Sheave Size

Voltage Selector

Thumbscrew

Power Switch & Fuse Card

Headstock
Fatigue Model vs. Data Comparison
(SL Fatigue Model Development)

Briden Supa75 0.125”
SL Inspection vs. Fatigue Tracking

• Inspection Systems *Can* Locate:
  – Defects
    » Cracks or pits
  – Diameter changes
    » Necking

• Inspection Systems *Cannot*:
  – Measure fatigue damage
  – Estimate SL life reduction due to the defects
  – Estimate remaining SL fatigue life
Slickline Job Data
(Example: Tension & Depth vs. Time)
% Fatigue Life Used Output
(Example)

Max Fatigue: 10.0133 %
  at 20400 ft
Fatigue at Surface: 6.2689 %

Current depth: 1000 ft
Current tension: 1600 lbs

Start Fatigue Real-Time

Slickline Selected: IPS STANDARD
Slickline – Case History 1

Background

• Sandvik 2RK66 0.108” slickline

• Slickline data acquisition system used to record field job data
  – Depth, tension, sheave size & configuration

• Field Data
  – 37 Individual job records (i.e. work on a single well)
  – Up to 7 downhole trips per well

• Slickline History
  – Time in service: 90 Days
Slickline
(Case History 1)

Assumptions

• Fatigue Calculated as GD31MO 0.108” Slickline

• Several Jobs Not Recorded (<10% of total)

• Rig Up: Dual-wheeled Measuring Head
  – Upper & lower sheave wheels (‘Type 3’ rigup)

• 6 m Slickline Cut Off after Each Job (avg.)

• No Exposure to Corrosive Environments
Fatigue Calculation
(Case History 1)

Results

- Slickline Retired with Only 20% Fatigue Life Used!
- Wasted $ for Unnecessary Line Replacement
Conclusion

• **Slickline Fatigue Software**
  – Display/record job data
  – Record line cuts & spooling events
  – Real-time remaining fatigue life
  – Can be utilized with DAS provided by numerous manufacturers
  – Generates post-job customer reports

• **Portable Fatigue Tester**
  – Test for corrosion
  – Fatigue life de-rating

• **Questions?**