Field Trial Testing of Q-Tough Wear Resistant Production Tubing

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Quantiam Technologies Inc. develops and commercializes disruptive new products based on Advanced Materials, Catalysts, Coatings and Surfaces.

**Petrochemical**
- **CAMOL**: Anti-Fouling Coatings for Olefins
- **SGX**: Super Coke Gasification
- **Inert-1300**: Inert at extreme temperatures

**CleanTech & Alternative Energy**
- **Green Chemistry**
  - Green H₂ (Water Splitting)
  - Green Fuels (CO₂ Splitting)
- **Methanol+**
  - Captured Carbon Conversion

**Oil & Gas and Oil Sands**
- **Wear and Corrosion Resistant Coatings**
  - Internal tube surfaces
  - External surfaces
  - Complex Geometries

**Aerospace & Defence**
- **High Temperature Wear & Corrosion Coatings for Weapon Barrels**
- **Ballistic Protection for Personnel and Vehicles**
Applied R&D and Advanced Manufacturing

Quantiam has extensive in-house materials development, characterization and advanced manufacturing facilities.
Quantiam’s cost-effective, proprietary coating manufacturing platform provides:

1. Non line-of-sight deposition (internal, external or complex geometries)
2. Metallurgical bonding for superior adhesion
3. Micro-composite structure for excellent toughness and thermal shock resistance
4. Macro coating thicknesses ranging from 50µm - 1mm (0.002” - 0.040”)
5. Part lengths up to 15 feet long
6. Compatibility with a wide variety of steels and other alloys
7. Customizable
Wear challenges in unconventional wells

- High costs are driven by the frequency of wear-induced failures and the cost of workovers.
- Sliding wear between the sucker rod and the inside of production tubing is among the most common causes of failures.
- Q-Tough was developed to address this issue and has been successfully field trialed in the Bakken region of North Dakota.
Q-Tough was developed to solve wear challenges in production tubing

- Cost-effective **non-line-of-sight** deposition process
- **High toughness** eliminates special handling
- **Smooth surface finish** and **unique composition** enables long runtimes **without accelerating wear of other components**
- Lab and field trial testing validates performance
Q-Tough

Metallurgical bonding

- No special handling requirements
- Eliminates delamination

Microcomposite structure

- Well dispersed hard particles (light grey)
- Ductile, corrosion resistant metallic matrix (grey)
Pin-on-Disk Wear Testing (ASTM G99)

Test conditions: Dry Sliding Wear
- 226.2 m sliding distance
- 20 N load, Si₃N₄ ball
- 300 rpm
- Volume loss measured optically

Shorter bars indicate higher wear resistance

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Pin-on-Disk Wear Testing (ASTM G99)

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- 226.2 m sliding distance
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<table>
<thead>
<tr>
<th>Material</th>
<th>Average Volume Loss (mm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q-Tough</td>
<td>0.0007</td>
</tr>
<tr>
<td>PTA (65% WC)</td>
<td>0.006</td>
</tr>
<tr>
<td>Electroplated Cr</td>
<td>0.352</td>
</tr>
<tr>
<td>Carbon Steel</td>
<td>0.349</td>
</tr>
</tbody>
</table>

> 500x vs carbon steel
Sand Abrasion Wear Testing (ASTM G65)

Test Conditions: Abrasive Wear
- Procedure A: 6000 revolutions
- Load: 30 lbf
- Sand flow rate: 300-400 g/min

Shorter bars indicate higher wear resistance
Sand Abrasion Wear Testing (ASTM G65)

Test Conditions: Abrasive Wear
  • Procedure A: 6000 revolutions
  • Load: 30 lbf
  • Sand flow rate: 300-400 g/min

Shorter bars indicate higher wear resistance

15x vs carbon steel
Slurry Jet Erosion Testing

Test Conditions: Slurry Wear
- Slurry flow rate: 16 m/s
- Erodent: AFS 50-70 silica sand
- Solid particle concentration: 9.1 wt%
- Impact angle: 20°, 45°, 90°
- Test duration: 2 hours

Shorter bars indicate higher wear resistance
Slurry Jet Erosion Testing

Test Conditions: Slurry Wear
- Slurry flow rate: 16 m/s
- Erodent: AFS 50-70 silica sand
- Solid particle concentration: 9.1 wt%
- Impact angle: 20°, 45°, 90°
- Test duration: 2 hours

Confidential Shorter bars indicate higher wear resistance

6 to 29x vs steel

AR400 steel

27%Cr 3%C white iron

Q-Tough

Cr Carbide overlay

Slurry Jet Erosion Volume Loss (mm³)
Q-Tough Field Trials

GOAL: To extend runtimes by installing coated tubes in known problem areas of the well
Q-Tough Field Trial Installations (44 wells)

<table>
<thead>
<tr>
<th>Total wells installed</th>
<th>Currently active</th>
<th>Pulled early (no Q-Tough failure)</th>
</tr>
</thead>
<tbody>
<tr>
<td>44</td>
<td>24</td>
<td>20</td>
</tr>
</tbody>
</table>

Run time (days)

- Prior Runtime
- Current Runtime

- 2015 Install
- 2016 Install
- 2017 Install

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Q-Tough Field Trial Results

- 3x - 4x increase in runtime (and counting)
- Earliest installations more than 4 years in service
- No coating related failures to date
- Benefits achieved by installing coated tubes in 60 to 100 ft in problematic areas of well
- No adverse effects on other components
Evaluation of field trial Q-Tough tubing

- Four Q-Tough coated tubes were removed early from one well during a workover to get an early snap-shot of coating degradation
- Well was worked over to replace a corroded pump plunger
- Well operated for 506 days before the workover
- This represents a **1.4x increase in runtime** compared to the well’s previous runtime
Evaluation of field trial Q-Tough tubing
Borescope and cross-sectional coating analysis

- All four tubes were non-destructively inspected with a borescope
- No damaged areas were observed

- Cross sectional samples were taken from the middle and ends of each tube
- Coating damage assessed with scanning electron microscopy (SEM)
Typical Field Trial Q-Tough Coating Microstructure

(506 days of operation downhole, 1.4x typical runtime)

Damaged coating
<25 µm thick
(<1.0 thou)

Undamaged coating
~350 µm thick
(~14 thou)

Metallurgical bond
Carbon steel
Typical Field Trial Q-Tough Coating Microstructure

(506 days of operation downhole, 1.4x typical runtime)

93% coating thickness remains after 500+ days

Damaged coating
<25 μm thick
(<1.0 thou)

Undamaged coating
~350 μm thick
(~14 thou)

Metallurgical bond

Carbon steel
Q•Tough coatings were developed to address wear challenges in production tubing

- **Q-Tough coatings have:**
  - Composite microstructures
  - Metallurgical bonding
  - Cost-effective non-line-of-sight manufacturing
  - Smooth surface finish and unique composition = long runtimes without accelerated wear of components

- **Field trials** of Q-Tough coatings have been installed in 44 wells in the Bakken region of North Dakota
  - In 4 years operation no coating related failures have occurred
  - Early stage evaluation of field trial coating observed that 93% of the coating remains undamaged after >500 days downhole
## Coating Property Summary

<table>
<thead>
<tr>
<th>Property</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Sliding Wear Resistance (ASTM G99)</td>
<td>&gt;500x better compared to uncoated J55 carbon steel</td>
</tr>
<tr>
<td>Sand Abrasion Wear Resistance (ASTM G65)</td>
<td>15x better compared to uncoated J55 carbon steel</td>
</tr>
<tr>
<td>Slurry Jet Erosion Resistance</td>
<td>Comparable to CrC overlays and white cast irons</td>
</tr>
<tr>
<td>Substrate Compatibility</td>
<td>Carbon and alloy steel, stainless steel, Ni-based alloys</td>
</tr>
<tr>
<td>Part Sizes and Geometries</td>
<td>Internal and External surfaces</td>
</tr>
<tr>
<td></td>
<td>Tubular and complex geometries</td>
</tr>
<tr>
<td></td>
<td>Lengths up to 15’ long</td>
</tr>
<tr>
<td>Average Microhardness</td>
<td>~800 Hv (63 HRC)</td>
</tr>
<tr>
<td>Coating Thickness</td>
<td>50-1000 µm (0.002” -0.040”)</td>
</tr>
<tr>
<td>Substrate-Coating Bond Strength</td>
<td>Excellent due to Metallurgical Bond</td>
</tr>
<tr>
<td>Coating Porosity</td>
<td>Minimal</td>
</tr>
<tr>
<td>Appearance</td>
<td>Smooth as coated finish</td>
</tr>
<tr>
<td></td>
<td>Coating applied as Light Grey</td>
</tr>
<tr>
<td></td>
<td>Finishes to a high metallic lustre when polished</td>
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</tbody>
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