Carbon Fiber Sucker Rods versus Steel and Fiberglass

Special Thanks to Mark Turland

O. Lynn Rowlan
Echometer Company
Carbon Fiber Rods Were Ran in Two Different Sucker Rod Lifted Wells

• Discuss before and after conditions using dynamometer data

• Carbon fiber rods used to replace 2800 feet of 1.25 inch fiberglass rod in one well.

• Carbon fiber rods used to replace 2800 feet of 1 inch steel N97 sucker rods in a second well.

• Compare carbon fiber sucker rods performance to the fiberglass sucker rods

• Compares carbon fiber sucker rods performance to the high strength N97 steel sucker rods.
Carbon Fiber Rods Weigh ¼ of Fiber Glass and Has 2 X Tensile Strength

### 04/10/2014 – Fiberglass Rod String

<table>
<thead>
<tr>
<th>Rod Type</th>
<th>Top Taper</th>
<th>Taper 2</th>
<th>Taper 3</th>
<th>Taper 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>4475.00</td>
<td>2100.00</td>
<td>1500.00</td>
<td>300.00</td>
</tr>
<tr>
<td>Diameter</td>
<td>1.250</td>
<td>1.000</td>
<td>0.875</td>
<td>1.625</td>
</tr>
<tr>
<td>Weight</td>
<td>5772.8</td>
<td>6073.6</td>
<td>3318.0</td>
<td>2300.5</td>
</tr>
</tbody>
</table>

**Fiber Glass**
- Wt/Ft – 1.29 lbs/ft
- Diameter – 1.25 in
- E – 7.1x10^6
- Density - 153.0 lbs/cu ft
- γ H2O/FG – 0.4079
- Tensile – 115,000 psi

### 02/24/2015 – Carbon Fiber Rod String

<table>
<thead>
<tr>
<th>Rod Type</th>
<th>Top Taper</th>
<th>Taper 2</th>
<th>Taper 3</th>
<th>Taper 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>2800.00</td>
<td>2250.00</td>
<td>2950.00</td>
<td>300.00</td>
</tr>
<tr>
<td>Diameter</td>
<td>0.625</td>
<td>1.000</td>
<td>0.875</td>
<td>1.625</td>
</tr>
<tr>
<td>Weight</td>
<td>901.6</td>
<td>6507.4</td>
<td>6525.4</td>
<td>2300.5</td>
</tr>
</tbody>
</table>

**Carbon Fiber**
- Wt/Ft – 0.32 lbs/ft
- Diameter – 0.625 in
- E – 23.6x10^6
- Density - 143.9 lbs/cu ft
- γ H2O/CF – 0.4336
- Tensile – 235,000 psi
04/10/2014 – Fiberglass Dyno
High Fluid Level with 37.1” Overtravel - Well 1

<table>
<thead>
<tr>
<th>Polished Rod Pump</th>
<th>Peak Load</th>
<th>Min Load</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>22.27 Klb</td>
<td>8.44 Klb</td>
<td>25.8  HP</td>
</tr>
<tr>
<td></td>
<td>4.37 Klb</td>
<td>-0.75 Klb</td>
<td>14.8  HP</td>
</tr>
</tbody>
</table>

Pump Displacement: 600 BBL/D
Calculated Fluid Load Max: 8.24 Klb
Surface Efficiency: -----%
Pumping Speed: 8.295 spm
Motor to Pump Efficiency: -----%
Pump Intake Pressure: 2006 psi (g)
Damp Up: 0.134
Damp Down: 0.134
Fillage: 98.67%
EPT: 202.4 in
Enter Tubing Pressure: 75.0 psi (g)

PDP = 3425 psi (g)

PIP FL = 1864 psi (g)

Stroke Length = 168.00 in
Fo Max = 8.24 KPD
Fo From Fluid Level (Fo FL) = 3.76 Klb

Stroke: 106 00:12:45
Unanchored KI: 763 lb/in
Kr: 121 lb/in

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Sept. 27 - 30, 2016
Deep Fluid Level with less 256 BPD Due to FG Stretch - Well 1

Polished Rod Pump
- Peak Load: 25.19 Klb
- Min Load: 8.36 Klb
- Power: 25.6 HP
- Peak Load: 9.06 Klb
- Min Load: -0.90 Klb
- Power: 20.2 HP

Pump Displacement: 344 BBL/D
Surface Efficiency: ----
Pumping Speed: 6.767 spm
Motor to Pump Efficiency: ----
Pump Intake Pressure: 370 psi (g)
Damp Up: 0.134
Damp Down: 0.134
Fillage: 92.19 %
EPT: 142.5 in

Stroke Length = 168.00 in
Unanchored Kt: 763 lb/in
Kp: 123 lb/in

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Deep Fluid Level with +13 BPD Due to less CF Stretch - Well 1

Peak Load | Min Load | Power
---|---|---
25.11 Klb | 8.73 Klb | 25.2 HP
7.81 Klb | -0.55 Klb | 18.7 HP

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02/24/2015 – Carbon Fiber Dyno
Deep Fluid Level with +67 BPD increased SPM from 6.77 to 7.09 - Well 1

Polished Rod Pump

<table>
<thead>
<tr>
<th>Peak Load</th>
<th>Min Load</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.01 Klb</td>
<td>7.95 Klb</td>
<td>28.1 HP</td>
</tr>
<tr>
<td>7.96 Klb</td>
<td>-0.62 Klb</td>
<td>20.6 HP</td>
</tr>
</tbody>
</table>

Pump Displacement 411 BBL/D
Calculated Fluid Load Max 8.94 Klb
Surface Efficiency ----- %
Pumping Speed 7.087 spm
Motor to Pump Efficiency ----- %
Pump Intake Pressure 816 psi (g)
Damp Up 0.134
Damp Down 0.134
Fillage 96.91 %
EPT 162.6 in
EPT Pressure 50.0 psi (g)
02/24/2015 – Carbon Fiber Dyno

Now Weight Heavy move IN 11 inch ~ Lighter Rod String – Well 1

Min Gearbox Torque, Upstroke
Max Gearbox Torque, Upstroke
Min Gearbox Torque, Downstroke
Max Gearbox Torque, Downstroke
RMS Gearbox Torque
AVG Gearbox Torque
Cyclic Load Factor

Existing
-342.1 Kin-lb
414.5 Kin-lb
-142.2 Kin-lb
883.1 Kin-lb
423.3 Kin-lb
255.8 Kin-lb
1.655

In Balance
-150.2 Kin-lb
630.3 Kin-lb
-293.9 Kin-lb
630.3 Kin-lb
378.1 Kin-lb
254.9 Kin-lb
1.483

Out of Balance

Maximum Counterbalance
Existing Counterbalance
Required Counterbalance Decrease

weights heavy
2142.5 Kin-lb
2130.8 Kin-lb
252.9 Kin-lb

To Balance Move 22.626 Klb weights IN

11.18 in
## 09/03/2014 – Steel N97 86 Rod String

<table>
<thead>
<tr>
<th>Rod Type</th>
<th>Top Taper</th>
<th>Taper 2</th>
<th>Taper 3</th>
<th>Taper 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>3000.00</td>
<td>3050.00</td>
<td>2350.00</td>
<td>200.00</td>
</tr>
<tr>
<td>Diameter</td>
<td>1.000</td>
<td>0.875</td>
<td>0.750</td>
<td>1.500</td>
</tr>
<tr>
<td>Weight</td>
<td>8676.6</td>
<td>6746.6</td>
<td>3815.1</td>
<td>1306.0</td>
</tr>
</tbody>
</table>

### N97
- Wt/Ft: 2.892 lbs/ft
- Diameter: 1.0 in
- E: $30.5 \times 10^6$
- Density: 490 lbs/cu ft
- $\gamma_{H2O/FG}$: 0.1273
- Tensile: 140,000 psi

## 02/20/2015 – Carbon Fiber Rod String

<table>
<thead>
<tr>
<th>Rod Type</th>
<th>Top Taper</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>2800.00</td>
<td>2250.00</td>
<td>2950.00</td>
<td>300.00</td>
</tr>
<tr>
<td>Diameter</td>
<td>0.625</td>
<td>1.000</td>
<td>0.875</td>
<td>1.625</td>
</tr>
<tr>
<td>Weight</td>
<td>901.6</td>
<td>6507.4</td>
<td>6525.4</td>
<td>2300.5</td>
</tr>
</tbody>
</table>

### Carbon Fiber
- Wt/Ft: 0.32 lbs/ft
- Diameter: 0.625 in
- E: $23.6 \times 10^6$
- Density: 143.9 lbs/cu ft
- $\gamma_{H2O/CF}$: 0.4336
- Tensile: 235,000 psi
Carbon Fiber Stress is Higher on 0.625” Rod, BUT 48% of Allowable is Lower

<table>
<thead>
<tr>
<th>Diameter (in) / Length (ft)</th>
<th>Grade</th>
<th>Modified Goodman (100%)</th>
<th>Stress (psi (g))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 3000</td>
<td>N97</td>
<td>77.9%</td>
<td>45564.3</td>
</tr>
<tr>
<td>0.875 3050</td>
<td>S-88</td>
<td>74.9%</td>
<td>42804.8</td>
</tr>
<tr>
<td>0.75 2350</td>
<td>N97</td>
<td>79.0%</td>
<td>40734.2</td>
</tr>
<tr>
<td>1.5 200</td>
<td>SB</td>
<td>31.7%</td>
<td>7145.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Diameter (in) / Length (ft)</th>
<th>Grade</th>
<th>Modified Goodman (100%)</th>
<th>Stress (psi (g))</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.625 2665</td>
<td>CF</td>
<td>48.0%</td>
<td>79863.4</td>
</tr>
<tr>
<td>0.875 2650</td>
<td>S-88</td>
<td>66.9%</td>
<td>39919.9</td>
</tr>
<tr>
<td>0.75 2900</td>
<td>N97</td>
<td>74.5%</td>
<td>40516.6</td>
</tr>
<tr>
<td>1.5 350</td>
<td>SB</td>
<td>30.6%</td>
<td>7060.4</td>
</tr>
</tbody>
</table>
N97: Stroke #53 02/10/15 02:44:44PM
Peak PRL 35,790 Lbs

Peak Load | Min Load | Power
---|---|---
Pumped Rod | 35.79 Klb | 10.14 Klb | 45.3 HP
Pump | 11.09 Klb | -0.58 Klb | 32.6 HP

Adjustable Pump Displacement: 501 BBL/D
Calculated Fluid Load Max: 12.10 Klb
Surface Efficiency:
Pumping Speed: 9.184 spm
Motor to Pump Efficiency: 549 psi (g)
Pump Intake Pressure:
Damp Up: 0.136
Damp Down: 0.136
Adjustable Fillage: 81.42 %
Adjustable EPT: 116.9 in
Enter Tubing Pressure: 130.0 psi (g)

Unanchored Kt: 518 lb/in
Kt: 177 lb/in
CF Rods Maintained Production w/ 1.75” Pump

**CF** (API: 25-175 RHBM 34-4)

<table>
<thead>
<tr>
<th>Peak Load</th>
<th>Beam Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>35787 Lbs</td>
<td>98%</td>
</tr>
<tr>
<td>24502 Lbs</td>
<td>67.1%</td>
</tr>
</tbody>
</table>

**N97** (API: 25-200 RHBM 22-4)

- **SPM:** 9.184
- **BPD:** 568
- **EPT:** 132
- **Peak Load:** 24502 Lbs
- **Beam Load:** 67.1%

- **SPM:** 9.137
- **BPD:** 552
- **EPT:** 168
- **Peak Load:** 11285 Lbs
- **Beam Load:** 98%

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Steel Rod Result in 912 Gear Box Over Load Both Up Stroke and Down Stroke

N97: Stroke #53 02/10/15 02:44:44PM

958.1 Kin-lb

988.0 Kin-lb

CF: Stroke #21 07/15/15 02:35:32PM

859.9 Kin-lb

689.1 Kin-lb
Acquired 400 HZ Dynamometer Data to Investigate Load Spikes on Pump Card Between TV Close to SV Open.

Load Spikes on Pump Card

Comments: Did a valve test at stroke 16, didn't record it. 400 Hz. No power data. Shut off.
For 1.59 Sec of the 6.54 Sec/Stroke the Rods Stretch to Pickup the Pump Load
Notice Bounce During 1st 1.5 Seconds

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Conclusion

- In these two wells the carbon fiber rods have longer down hole stroke than either fiberglass or steel sucker rods.
- Carbon fiber rods gear box in-balance loading is less than either fiberglass or steel sucker rods.
- 0.625 inch carbon fiber peak rod stress is higher than the peak stress on the 1 inch N97 rods, but the carbon fiber rods were loaded to 48% of the modified Goodman allowable stress.
- As wells are drilled to deeper depths higher strength rods will likely be required.
- Stronger lighter carbon fiber rods have the potential to be used to produce sucker rod wells to extremely deep depths.
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