Sucker Rods

New Premium Connection Design for High Load Operations
Premium Connection Sucker Rods

Agenda

• Standard API rod design scenario

• Tenaris Premium Connection

• Solving the problem…
  – Finite Elements Analysis (FEA)
  – Laboratory Full Scale Tests
  – Field Experience
  – Make-up Process
  – Manufacturing & Quality Control

• Conclusions
Standard API rod design scenario

• Conventional Pumping is the most popular system for oil production in the world (>600,000 oil wells).
• Over 30% of system failures are due to fatigue in the connection.
• Pin fatigue resistance < body (Efficiency<100%)
• Need to adopt high resistance grades
• Rod size limited by the tubing ID (e.g. 2 7/8")
Standard API rod design scenario

Several physical limitations to deal with:

- Connection loosing (gap on the thread).
- Thread deformation during make-up and operation.
- Non-uniform stress distribution along the thread profile.
- Make-up operation (over or under torque).
- Thread damage (threads deformations, alignment, etc.).
- Corrosion.

It has been the driver to develop a new connection concept design!
Tenaris Premium Connection

The target was to develop a special connection capable of withstanding high working loads improving the fatigue life.
Solving the problem

• Loosening tendency (cylindrical thread, one-flank contact thread, make-up based on high axial interference).

• Non-uniform stress distribution on the thread profile.

• High make up stress creates plastic deformation on the threads and limits the working load capacity.
Finite Elements Analysis

This design tool was used to select the most suitable thread before testing. Many alternatives and comparisons with the API thread were made.

Simulation and testing material: D Grade Rod/ UHS couplings
Premium Connection Sucker Rods

Finite Elements Analysis (FEA)

3D Simulation

(Deviated well evaluation)
Laboratory Full Scales Tests
Axial Fatigue tests – MTS Equipment
Laboratory Full Scales Tests
Connection Fatigue Tests Results (3/4”)

Test sample: 7/8” Grade D Pony rods with 3/4” Premium Connection pin (UHS Premium Connection Couplings)

<table>
<thead>
<tr>
<th></th>
<th>API 3/4”</th>
<th>Premium 3/4”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cmax (Ton)</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Cmin (Ton)</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>% Goodman</td>
<td>279.8</td>
<td>308</td>
</tr>
<tr>
<td>Cycles (MM)</td>
<td>2.96 Pin failure</td>
<td>4.87 Pin failure</td>
</tr>
</tbody>
</table>

Less than 5 Million Cycles

10 Million Cycles without failure (up to 336 %Goodman)
## Laboratory Full Scales Tests
### Connection Fatigue Tests Results (7/8”)

Test sample: 1 1/8” Grade D rod body with 7/8” premium Connection pin (UHS Premium Connection Couplings).

<table>
<thead>
<tr>
<th></th>
<th>API 7/8”</th>
<th>Premium 7/8”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cmax (Ton)</td>
<td>22</td>
<td>16 16.5 17</td>
</tr>
<tr>
<td>Cmin (Ton)</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>% Goodman</td>
<td>300.7</td>
<td>194.6 203.4 212.3 221.2 230 300.7 318.7 336</td>
</tr>
<tr>
<td>Cycles (MM)</td>
<td>1.4 pin failure 1.271 Coupling failure</td>
<td>10</td>
</tr>
</tbody>
</table>

Less than 1.5 Million Cycles
10 Million Cycles without failure (up to 336 %Goodman)
Laboratory Full Scales Tests
Connection Fatigue Tests Results (1”)

Test sample: 1 1/8” Grade D rod body with 1” Premium Connection pin (UHS Premium Connection Couplings).

<table>
<thead>
<tr>
<th>Premium 1”</th>
<th>23</th>
<th>25</th>
<th>27</th>
<th>28.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cmax (Ton)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cmin (Ton)</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Goodman</td>
<td>223.5</td>
<td>247.8</td>
<td>262.3</td>
<td>280.5</td>
</tr>
<tr>
<td>Cycles (MM)</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

10 Million Cycles without failure (up to 280 %Goodman)
Premium Connection Sucker Rods
Fatigue Tests Results

Goodman Diagram HS & D Grade Rods

- 1” D PC Rods
- 7/8” D PC Rods
- 3/4” D PC Rods

Min YS D Grade (Ksi)
S allowable D Grade (Ksi)
Min YS HS Grade (Ksi)
S allowable HS Grade (Ksi)
Smin (Ksi)
Smax (Ksi)
Field Experience (Well 01)

A field trial well is operating with a 7/8” D Grade Premium Connection taper in a High Strength string:

- **Pump depth**: 7155 ft (2181 m)
- **Pump bore size**: 2”
- **Tubing**: 2 7/8”
- **Production**: 478 bpd (76 m³/d)
- **Pumping Unit**: M 912-365-168
- **Stroke**: 168”
- **SPM**: 7.81
- **Oil Gravity**: ~10 °API
- **String Design**:
  - 93 1” High Strength rod 83 % Goodman (SF 0.9)
  - 94 7/8” Grade D PC rod 137 % Goodman (SF 0.9)
  - 77 ¾” High Strength rod 81 % Goodman (SF 0.9)
  - 20 1½” Sinker Bars

Installation Date: September 23rd 2005

Accumulates 8 million strokes working at 137 % Goodman (SF 0.9).
Field Experience (Well 01)

The Grade D rod with Premium Connection works in similar conditions as High Strength rods, indicating that the latter could be replaced by the first ones.
A second field trial well is operating, also with a 7/8” D Grade Premium Connection taper:

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump depth</td>
<td>7995 ft (2437 m)</td>
</tr>
<tr>
<td>Pump bore size</td>
<td>2 1/4”</td>
</tr>
<tr>
<td>Tubing</td>
<td>2 7/8”</td>
</tr>
<tr>
<td>Production</td>
<td>427 bpd (68 m³/d)</td>
</tr>
<tr>
<td>Pumping Unit</td>
<td>M 912-365-168</td>
</tr>
<tr>
<td>Stroke</td>
<td>168”</td>
</tr>
<tr>
<td>SPM</td>
<td>8.2</td>
</tr>
<tr>
<td>Oil Gravity</td>
<td>~10 °API</td>
</tr>
<tr>
<td>String Design</td>
<td>90 1” High Strength rod 90 % Goodman (SF 0.9)</td>
</tr>
<tr>
<td></td>
<td>136 7/8” Grade D PC rod 171 % Goodman (SF 0.9)</td>
</tr>
<tr>
<td></td>
<td>70 3/4” High Strength rod 95 % Goodman (SF 0.9)</td>
</tr>
<tr>
<td></td>
<td>24 7/8” Grade D as Sinker Bars</td>
</tr>
</tbody>
</table>

Working Period: December 3rd 2005 to January 2007 (extracted after two failures in 1” pin and one in 3/4” pin)

Accumulated 4.3 million strokes working at 170 % Goodman (SF 0.9).
Field Experience (Well 02)

The Grade D rod with Premium Connection works in similar conditions as High Strength rods, indicating that the latter could be replaced by the first ones.
The make-up is a five steps process:

1- Threads Cleaning
2- Dope Applying
3- Hand tight
4- Pin/Box contact control (with power tong)
5- Circumferential displacement control
Make-up process

Step #1: Threads Cleaning

Complete remove of solid particles must be assured.
Make-up process

**Step #2: Dope applying**

Standard tubing dope applying is recommended in order to avoid galling on the thread.
Make-up process

Step #3: Hand-tight

Hence the thread has diametric interference after hand tight the connection still shows a stand-off between pin a box shoulders.
Step #4: Pin/Box shoulder contact control

A power tong is required in order to make contact between pin and box shoulders (a 0,05 mm gauge is used for its control).

Step #5: Circumferential Displacement Control

After shoulder contact is assured a vertical line is drawn and by applying power torque the required circumferential displacement is achieved.
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Conclusions

• The connection is 100% efficient for high loads:
  Connection resistance > body resistance

• Higher fatigue life than API design was proved with fatigue tests.

• The connection performance allows the use of Grade D rods in high load wells where High-Strength Rods are required (Special HT and high alloy steel).

• The connection load capacity allows us to reduce the rod size in the string.
Thank you very much!