API RP 11BR Revisions on Sucker Rod Makeup

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The successful application of threaded and coupled rods to provide power to lift downhole fluids is critically dependent on proper makeup procedures. This is applicable whether the pump is a reciprocating, positive displacement sucker rod lift system or a rotary driven, progressing cavity pump system. This presentation will discuss new revisions to API RP 11BR, “Recommended Practice for the Care and Handling of Sucker Rods,” provide discussion for newly developed draft recommendations for progressing cavity pump installations as well as review the various parameters that affect proper connection preload.
Specification for Sucker Rods, Polished Rods and Liners, Couplings, Sinker Bars, Polished Rod Clamps, Stuffing Boxes, and Pumping Tees

API SPECIFICATION 11B
TWENTY-SEVENTH EDITION, MAY 2010
EFFECTIVE DATE: NOVEMBER 1, 2010

API Recommended Practice 11BR

Recommended Practice for the Care and Handling of Sucker Rods

API RECOMMENDED PRACTICE 11BR
NINTH EDITION, AUGUST 2008

• API Recommended Practice 11BR, Ninth Edition, August 2008, “Recommended Practice for the Care and Handling of Sucker Rods,” covers the care and handling of steel sucker rods, including guidelines on selection, allowable stress, proper joint makeup, corrosion control and used rod inspection for sucker rods in reciprocating, positive displacement sucker rod lift systems.
ISO 15136-3

• ISO 15136-3, Progressing Cavity Pump Systems for Artificial Lift, “Part 3 – Drive Strings”
  – Working draft provides the requirements for the design, design verification and validation, manufacturing and data control, performance ratings, functional evaluation, handling and storage of drive strings used in PCP systems.
API RP 11BR – Revisions

• Format change:
  – The revision uses separate annexes for products, running and pulling, calibration, corrosion control, inspection facilities, calibration requirements, etc.

• Additional products included:
  – High strength sucker rods, polished rods and liners, sinker bars, polished rod clamps, stuffing boxes and pumping tees.

• Expanded sections:
  – Selection of API Steel Sucker Rods
  – Allowable Sucker Rod Stress Determination Utilizing Range of Stress
  – Sucker Rod Joint Makeup Utilizing Circumferential Displacement
Revisions – continued . . .

Expanded sections – continued . . .

– Transportation and Handling, Storage, Running and Pulling (of all equipment listed)
– Running and Pulling (of all equipment listed)

• New sections on:
  – Minimum Requirements for Inspection Facilities Inspecting Products Manufactured in Accordance with API Specification 11B.
  – Non Destructive Methods of Inspecting New Steel Sucker Rods, Fiberglass Rods, Sinker Bars, Polished Rods and Couplings.
  – Non Destructive Methods of Inspecting Used Steel Sucker Rods, Fiberglass Rods, Sinker Bars, Polished Rods and Couplings.
  – Mechanical Properties Testing of 11B Products
Parameters That Affect Proper Connection Preload Stress

• For optimum performance, it is imperative that all of the connections in the rod string be made up to a given preload stress level in order to prevent separation between the bearing surfaces (i.e., pin shoulder and coupling face) during the pumping cycle.

• If the preload stress is greater than the applied load, no failure will occur.

• Both test data and theoretical calculations show that circumferential displacement beyond hand-tight makeup of the coupling and pin provides an accurate and repeatable means to measure and define the preload stress in a sucker rod connection.
Parameters That Affect Proper Connection Preload Stress

There are many inherent variables which affect sucker rod connection makeup. These variables include, but are not limited to:

- Rod grade and size,
- Dimensions, tolerances and surface finish of the bearing surfaces and threads,
- Cleanliness of the pin and coupling threads,
- Selection, type, amount, condition, method of application, and temperature rating of an acceptable thread lubricant,
- Cleanliness and dryness of the bearing surfaces,
- Thermal affects,
- Knowledge and skill of the well servicing crew,
- Optimum preload stress,
Parameters That Affect Proper Connection Preload Stress

Variables – continued . . .

- Operating conditions (i.e., overloads, fluid pound, friction effects, vibration, contact wear, rod buckling tendencies, etc.) and

- In service failures (i.e., failures can lead to more failures if the root cause has not been identified and remedied.

• As a result, applied torque has proven to be inaccurate and not capable of measuring the preload stress level in a sucker rod connection.
Sucker Rod Connections

- The sucker rod connection is affected by tensile loads that try to pull the connection apart.
- The tensile loads are roughly parallel to the axis of the rod body and try to stretch or separate the bearing surfaces (i.e., the pin shoulder and coupling face).
- The tightening of the coupling on the pin produces a tensile pre-stress load in the pin, which is approximately equal to the compressive stress introduced in the coupling material.
- A tension load, no matter how small, will add to the pre-load stress in the connection and partially relieve the connection prestress.
- The behavior and life of the sucker rod connection depends on how tightly the coupling clamps and how long the pin can maintain its preload stress.
Connection Preload Stress

- The clamping force created during the tightening of the coupling stretches the pin similar to a spring.
- The “spring” effect exerts a clamping force on the pin shoulder and coupling face (i.e., bearing surface) that remains only as long as the pin is stretched.
- Any applied service load or condition, which relaxes the pin or reduces the clamping force, will release some of the spring’s energy (i.e., clamping force).
Connection Preload Stress

- A plot of the von Mises distribution in the 7/8-inch API Grade C Sucker Rod and standard coupling, courtesy of Sandia National Laboratories, illustrates the stresses in the pin and coupling as axial forces are applied to the sucker rod connection.

1. Preload (no axial load)
2. Maximum compression (-5 ksi)
3. Maximum tension (40 ksi)
Preload Stress Determination

• A number of torque-measuring methods exist, starting with the operator’s “feel” and ending with installing strain gages on the bolt. The accuracy in determining the applied torque value is cost dependent. Tables VII and VIII are by two different “experts,” and their numbers vary. However, they both show the same trends of cost versus torque accuracy.

# Torque-Measuring Methods

Table VII – Industrial Fasteners Institute's Torque-Measuring Method

<table>
<thead>
<tr>
<th>Preload Measuring Method</th>
<th>Accuracy, %</th>
<th>Relative Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feel (operator’s judgment)</td>
<td>± 35</td>
<td>1</td>
</tr>
<tr>
<td>Torque wrench</td>
<td>± 25</td>
<td>1.5</td>
</tr>
<tr>
<td>Turn of the nut</td>
<td>± 15</td>
<td>3</td>
</tr>
<tr>
<td>Load-indicating washers</td>
<td>± 10</td>
<td>7</td>
</tr>
<tr>
<td>Fastener elongation</td>
<td>± 3 to 5</td>
<td>15</td>
</tr>
<tr>
<td>Strain gages</td>
<td>± 1</td>
<td>20</td>
</tr>
</tbody>
</table>

# Table VIII – Machine Design’s Torque-Measuring Method

<table>
<thead>
<tr>
<th>Type of Tool</th>
<th>Element Controlled</th>
<th>Typical Accuracy Range, % of Full Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slug wrench</td>
<td>Turn</td>
<td>1 Flat</td>
</tr>
<tr>
<td>Bar torque wrench</td>
<td>Torque / Turn</td>
<td>± 3 to 15 / ¼ Flat</td>
</tr>
<tr>
<td>Impact wrench</td>
<td>Torque / Turn</td>
<td>± 10 to 30 / ± 10 to 20°</td>
</tr>
<tr>
<td>Hydraulic Wrench</td>
<td>Torque / Turn</td>
<td>± 3 to 10 / ± 5 to 10°</td>
</tr>
<tr>
<td>Gearhead air-powered wrench</td>
<td>Torque / Turn</td>
<td>± 10 to 20 / ± 5 to 10°</td>
</tr>
<tr>
<td>Mechanical multiplier</td>
<td>Torque / Turn</td>
<td>± 5 to 20 / ± 2 to 10°</td>
</tr>
<tr>
<td>Worm-gear torque wrench</td>
<td>Torque / Turn</td>
<td>± 0.25 to 5 / ± 1 to 5°</td>
</tr>
<tr>
<td>Digital torque wrench</td>
<td>Torque / Turn</td>
<td>± ¼ to 1 / ¼ Flat</td>
</tr>
<tr>
<td>Ultrasonically controlled wrench</td>
<td>Bolt elongation</td>
<td>± 1 to 10</td>
</tr>
<tr>
<td>Hydraulic tensioner</td>
<td>Initial bolt stretch</td>
<td>± 1 to 5</td>
</tr>
<tr>
<td>Computer-controlled tensioning</td>
<td>Simultaneous torque &amp; turn</td>
<td>± 0.5 to 2</td>
</tr>
</tbody>
</table>

One of the methods for determining connection preload stress was developed in the 1960’s. This method correlates strain gauge readings in the laboratory versus the applied torsional load during makeup and the resulting movement of the coupling to provide the required connection preload stress.

This method is known as circumferential displacement (CD).
Circumferential Displacement Method

- Circumferential displacement (CD) is the distance measured, after makeup in the hand-tight position, between the displaced parts of a vertical line scribed across the external surfaces of the coupling and pin.
CD Minimum Values

- Sucker rod manufacturer’s should provide the optimum CD values for their products.
- These CD values are the recommended displacements required to achieve a minimum connection preload stress. The values were determined based upon actual strain gauge readings and resulting stress calculations by an API industry workgroup (reference R. Stevens and N. Hein, Jr.: “Circumferential Displacement – Partial History of the Industry Practice”, Southwestern Petroleum Short Course, 2010, Lubbock, Texas).
- However, API RP 11BR provides minimum values if these values are not available from the manufacturer.
These CD values are the recommended displacements required to achieve a minimum connection preload stress. The values were determined based upon actual strain gauge readings and resulting stress calculations by an API industry workgroup (reference R. Stevens and N. Hein, Jr.: “Circumferential Displacement – Partial History of the Industry Practice”, Southwestern Petroleum Short Course, 2010, Lubbock, Texas).
Computerized Rod Tongs

- Newer methods for determining adequate connection preload stress are based on torque turns or torque displacement. These new methods utilize computerized rod tongs to measure applied torque and either the number of turns or the final displacement of the coupling to the pin shoulder.

- These methods may be used for the larger diameter, high strength and specialty rods (i.e., 1 ¼” & 1 ½” Drive Strings) where current CD values may not be provided from the manufacturer.

- However, it should be noted, computerized rod tongs have not been widely used to date due to their limited availability.
Sucker Rod Thread Lubricant Selection

- Sucker rod thread lubricants shall be selected based on the following test procedure utilizing a new sucker rod pin end and a new sucker rod coupling.

1. Apply thread lubricant to the pin threads, per manufacturer’s recommendations.

2. Makeup the connection to the hand-tight position.

3. Apply the appropriate CD value for the rod size and grade.
sucker rod thread lubricant selection – continued . . .

4. Completely disassemble the connection.

5. Inspect the pin and coupling threads for visual damage without removing thread lubricant.

6. Without applying new or additional thread lubricant, repeat steps 2, 3, 4, and 5 for 10 complete cycles.

7. Completely disassemble the connection.

8. Clean and inspect the pin and coupling threads.

• An acceptable thread lubricant is one which results in no visible damage or galling of either thread forms related to the lack of lubricity after completing the above procedure.
Conclusions and Recommendations

• Revisions to API Recommended Practice 11BR should greatly benefit the industry and ISO 15136-3, Progressing Cavity Pump Systems for Artificial Lift, “Part 3 – Drive Strings” will provide valuable information for users of PCP systems.
• Proper connection preload is required to keep a screwed together connection firmly held together and reduce connection failures.
• Measuring torque to try to obtain the correct preload is accurate to within $\pm 25\%$
• Measuring strain is the most accurate but impractical in the field
• Newer computerized methods of measuring applied torque and displacement is accurate to $\pm 1$ to $2\%$
• The extension of the laboratory strain measurements to determine a more practical field method of circumferential displacement (CD) has proven accurate and is the industry recommended method
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