A Case for Developing a Wear Model for Sucker Rod System Design

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We are installing sucker rod pumps on deeper and more deviated than in the past
- Wear, due to sideload, is more important than before

Should we make wear considerations more prominent in the design process?

Do we need a model that predicts wear rates/runtimes?
Deeper Wells

- Over time, we are drilling for deeper and tighter reservoirs
- The shallow, high-permeability reservoirs were easier to find and more economical to develop

Depth of US Development Wells
US Energy Information Administration
Oil wells drilled horizontally are among the highest-producing wells.

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  - Oil wells drilled horizontally are among the highest-producing wells
“Crooked holes in the Permian Basin are common and are the most common cause of abrasion of the rod string. Continual rubbing of the rods against the sides of the well bore as it moves up and down the hole can eventually wear through the rod and cause failure”

- http://www.utpb.edu/ceed/energy-resources/petroleum-library/production/facilities/sucker-rods

“A WEB-BASED FAILURE DIAGNOSIS AND FREQUENCY REDUCTION SYSTEM, FEATURING IMAGING OF ROD-PUMPED PRODUCING WELLS”
John Rogers, Simon Ward, VisuWell. ALRDC 2008 Sucker Rod Pumping Workshop
Figure 13 – Spraberry Trend well with failures in high side load zone above pump
Operating Practices to Reduce Wear

- Drilling rod pump friendly wells; doglegs manageable
- Completion methods to minimize solids production
- Cleanout methods to minimize solids production
- Intake screens and/or bottomhole assembly strategies to reduce sand
- Reduce pump speed (SPM – strokes per minute)
- Rod Pump Control
- Sinker bars (vertical wells)
- Tubing anchors
- Corrosion inhibitor
- Swapping pony rods from top to bottom, to move coupling wear pattern
- No bent rods or crimped tubing
- Tubing string flipping (bottom to top)
- Rod guides
- Rod rotators
- Tubing coating/liner
- Coupling surface metallurgy
Industry Working on Wear

- **Tubing**
  - “Successful Oil and Gas Production Well Applications of Thermoplastic Lined Downhole Tubing: Protecting Horizontal Well Tubing and Pumping Around the Bend”
    - Davis & Hickman, 2012 ALRDC Sucker Rod Pumping Workshop (internally lined tubing)
  - “A New Advanced Material Sucker Rod Coupling: Economical Solution for Downhole Wear in Deviated Bakken Unconventional Wells”
    - Garza, Long, Bunsen, 2009 Southwest Petroleum Short Course, (internally hardened tubing)

- **Rod Couplings**
  - “A New Advanced Material Sucker Rod Coupling: Economical Solution for Downhole Wear in Deviated Bakken Unconventional Wells”
    - Silverman et al, 2016 ALRDC Rod Pump Workshop (enhanced couplings)
  - “Wear Resistant Coatings for Sucker Rod Couplings”
    - Zhao et al. ALRDC Sucker Rod Pump Workshop September, 2013 (enhanced couplings)
Fatigue
Fatigue Calculations

- Modified Goodman based on empirical tests
- The testing shown at right may give you a better relative comparison of rod performance than Modified Goodman
- Fatigue life can be variable even in a controlled environment

Steel Sucker Rod Fatigue Testing – Update on Phase I, Hein and Eggert, ALRDC Sucker Rod Workshop, 2012
Advances in rod manufacturing, including QA/QC, allow rods to have much longer runtimes than when Modified Goodman was adapted by API

- SPE 26558, Hein and Hermanson

In corrosive environments, we are now disregarding design criteria to some degree, overloading (non-high strength) rods and still expecting competitive fatigue runtimes.
Fatigue is less often a driver of high failure rates

- Wear, Corrosion, Solids, Scale, Paraffin, etc. are responsible for runtimes that end before fatigue life
- If every well ran to its rod fatigue life, we’d probably be pretty pleased about it

In many wells, wear is more likely to produce a shorter runtime than fatigue
The rod design process features three main load calculations:

1. Sucker rod load
2. Unit/structure load
3. Gearbox load

For Wear:

- Calculates compression/buckling
- Calculates sideload for deviated intervals
  - Sideload < 200 lbf
  - Sideload < 50 lbf/guide
- Min/Max PPRL > 0.2
  - PPRL – Peak Polished Rod Load
- SL x SPM < 1,500
  - SL – stroke length, inches, SPM – pump strokes per minute
Wear Model
Variable Environments for Wear

- Tubing grades: J55, L80
- We have 2 main types of couplings
  - Spray Metal and T Couplings
    - Variable coupling thickness
- Variable fluids present
  - Water only, or oil / water cuts
    - Oil lubricity may vary
  - Chemicals (films, come and go)
    - Corrosion inhibitor
- Stroke length when couplings contacting the tubing
  - At what deviation does the rod body also contact the tubing?
  - Changes as coupling wears, more rods contact tubing?
- Other issues – avoid wells with solids, scale, paraffin, pump fillage, etc.
- Need to keep careful control on the variables when testing
How much sideload and cycles produces the measured wear?

Tubing caliper data (at right) or tubing inspection data can be used.

Fig. 1—Example of downhole tubing caliper survey showing wear at the sucker-rod-string couplings and secondary tubing wear between couplings because of sucker-rod buckler and associated metal contact.

http://petrowiki.org/Subsurface_equipment_for_sucker-rod_lift
Tubing caliper data could be used to determine if wear is variable by rod position
- This sample appears to have more wear higher in the stroke/channel
- Also identify buckling wear
Calibrate non-compression wear in intervals where:

- Sideload and cycles are known, good tubing inspection data

Develop an empirical relationship between sideload and cycles versus wear rates

- Coupling wear for more vertical sections; guide wear for deviated
- Other potential considerations:
  - Higher wear at higher rod speeds
  - Effect of generated heat?
  - Affected by tension in material at contact point?

Use that empirical relationship that predicts wear, to back in to the sideloads created by compression/buckling
Theoretical Runtime Chart – Vertical Well

- Chart assumes coupling contacting tubing (nearly vertical well)
- Without enough deviation for the rod body to contact the tubing, PPRL and minor deviation will drive sideload/wear IF there is no rod buckling
- Instead of targeting some cycle count threshold, could we come up with a runtime prediction, based on cycles at a given SPM?
  - Stroke length important here because it determines coupling travel on tubing wall
  - Higher speeds, longer stroke lengths, and higher loads result in shorter runtimes

Uncalibrated & Theoretical – Vertical well, wear proportional to inches of rod travel, no accounting for deviation or buckling
Assumes wear driven by tubing wear not just coupling wear
- Guide wear until coupling exposed
- Rod body on tubing wear for un-guided

Assumes wear is a linear function of sideload and SPM
- $2 \times \text{Sideload} = 2 \times \text{wear}$
- $2 \times \text{SPM} = 2 \times \text{Wear}$

Can you take a point, or cloud of points you trust, from your conditions that produce wear failures, and proportion from that point out these curves?

Apply factors for different couplings, higher guides/rod, oil lubricity, tubing surface, sand and solids, pump fillage, daily runtime, etc.

Theoretical Proportioned Runtime - Deviated

**Guided (Assumed, not real data)**

| Sideload, lbf | 200 |
| Pumping Speed, SPM | 4 |
| Runtime, years | 4 |
| Cycles to failure | 8409600 |

**Unguided (Assumed, not real data)**

| Sideload, lbf | 60 |
| Pumping Speed, SPM | 4 |
| Runtime, years | 1.5 |
| Cycles to failure | 3153600 |

**Couplings (Unguided)**
- Guides per Rod
- Oil & Water, or Water?
- Tubing Size?
- Sand, Scale, Paraffin, etc.?
- Pumping, Hrs/Day?

**Hypothetical Sideload vs. Runtime**

DO NOT USE!
- You must create a chart that represents your conditions
- Only applies for a specific set of conditions

Uncalibrated &Theoretical – Deviated wells, to be based on know data from your field conditions, wear proportional to pump cycles and sideload, no accounting for stroke length, higher wear rates at higher SPM, deviation or buckling.
Wear is playing a more prominent role in failures.
An empirical model for wear based on sideload cycles, and rod speeds would help in the design process.
- Sideload due to tensile load, deviation, and buckling.
For a given set of conditions, will wear or fatigue determine runtime/economics?
Questions and Suggestions?
• Backup slide
Fatigue

- (Modified Goodman) usually doesn’t account for these in the design:
  - Un-measured deviation, not enough data granularity
  - Sticking pumps
  - Paraffin weight
  - Tagging & fluid pound
  - Changing or non-design fluid ratios
  - Actual vs. design conditions
    - Speeds & Harmonics
  - Handling & Makeup
  - Manufacturing & QA/QC
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