



## › PCP ROD STRING FATIGUE

3/24/2022

## › OUTLINE

- **What is fatigue?**
- **Randomness of fatigue**
- **Factors which affect fatigue life in PCP systems**
- **Corrosion**
- **Bending stress and concentration of curvature**
- **Strategies for improving fatigue life**

## › WHAT IS FATIGUE?

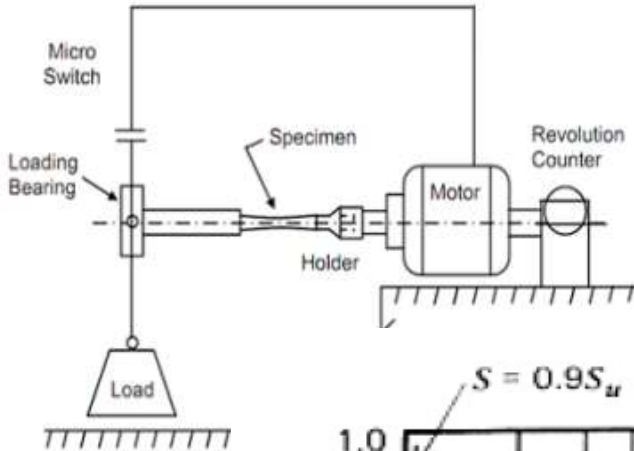
- **Fatigue failures happen when loads are cyclic.**
- **Fatigue cracks grow from microscopic imperfections in the material – but they only grow when the load changes**
- **There are numerous factors which can affect fatigue**
- **In a PCP application, the most significant form of cyclic load is usually caused by bending. When a rod rotates in a deviated well, there is a bending stress that cycles with each revolution.**

This bending stress is usually quite small relative to the stress from torque and tension, but over millions of cycles, it can lead to fatigue failures

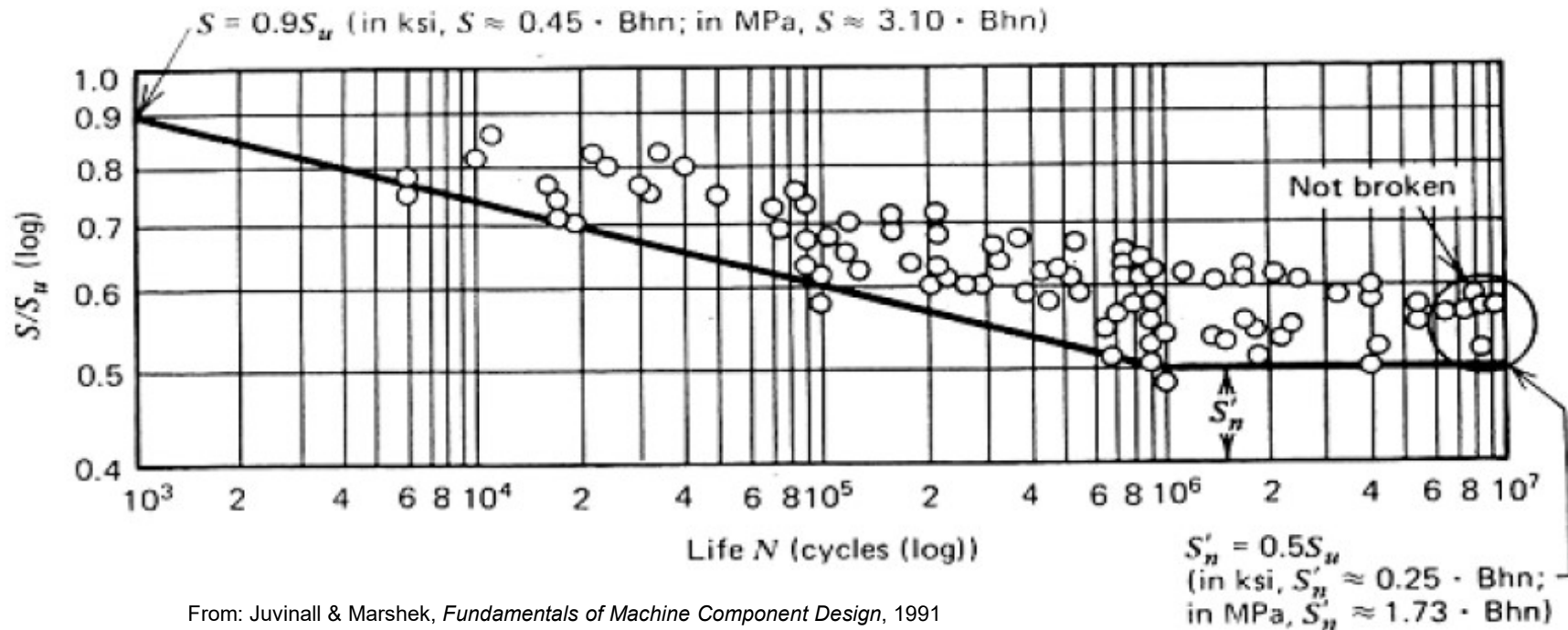
## › FATIGUE FAILURES OF PCP RODS



## › FATIGUE IS RANDOM



We cannot predict when a fatigue failure will happen – only the earliest time when it might happen



From: Juvinall & Marshek, *Fundamentals of Machine Component Design*, 1991

## › FACTORS WHICH AFFECT FATIGUE LIFE

- Torque
- Tension
- Rod diameter
- Coupling or centralizer diameter
- Wellbore curvature
- Distance between upsets
- Material properties
- Corrosion
- New/used rod

## › FACTORS WHICH AFFECT FATIGUE LIFE (CONT'D)

- **Mean stress**

Torque, tension, rod diameter

- **Alternating stress**

Bending stress, affected by rod diameter, and effective curvature in the rod

- **Material properties**

Ultimate strength, material S-N curve, surface properties

- **Corrosion**

- **Used rods**

In applications where fatigue is a problem, rods should be inspected before reuse

Tracking run life of rods may be difficult

## › CORROSION

- **This is a set of S-N curves**

S=stress, N=number of cycles

- **There is 0 mean stress, the stress shown is fully alternating**

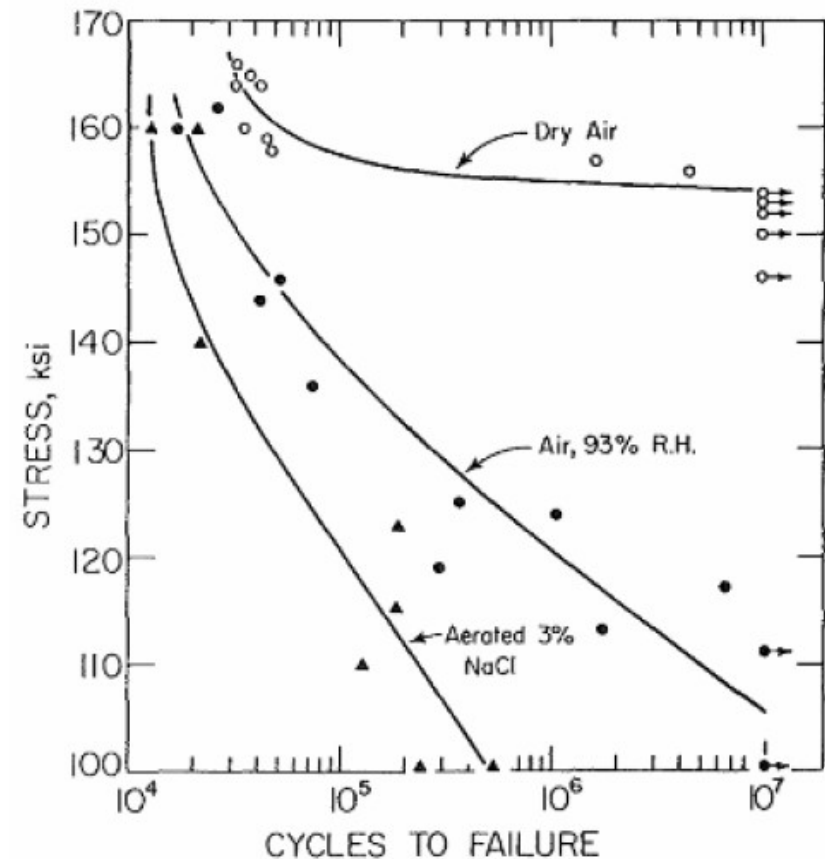
Not directly applicable to PCP applications

Needs to be converted

- **In dry air (no corrosion), this steel may not have a fatigue failure at all if the stress is under 155 ksi**

Called the “endurance limit”

- **In more corrosive environments, the life is significantly reduced and there is no endurance limit**



From: McEvily, *Atlas of Stress-Corrosion Fatigue Curves*, 1990



## › BENDING STRESS

- **Bending stress is a function of the rod size and curvature**

$$\sigma_{bend} \propto E \times D \times DLS$$

- **However, the wellbore DLS is not evenly distributed along the rod—we need to know the maximum curvature in the rod**
- **Curvature is concentrated near the connections**

Example: 1" rods, full size couplings, 5°/30m DLS, 20000 N tension: effective curvature is > 30°/30m

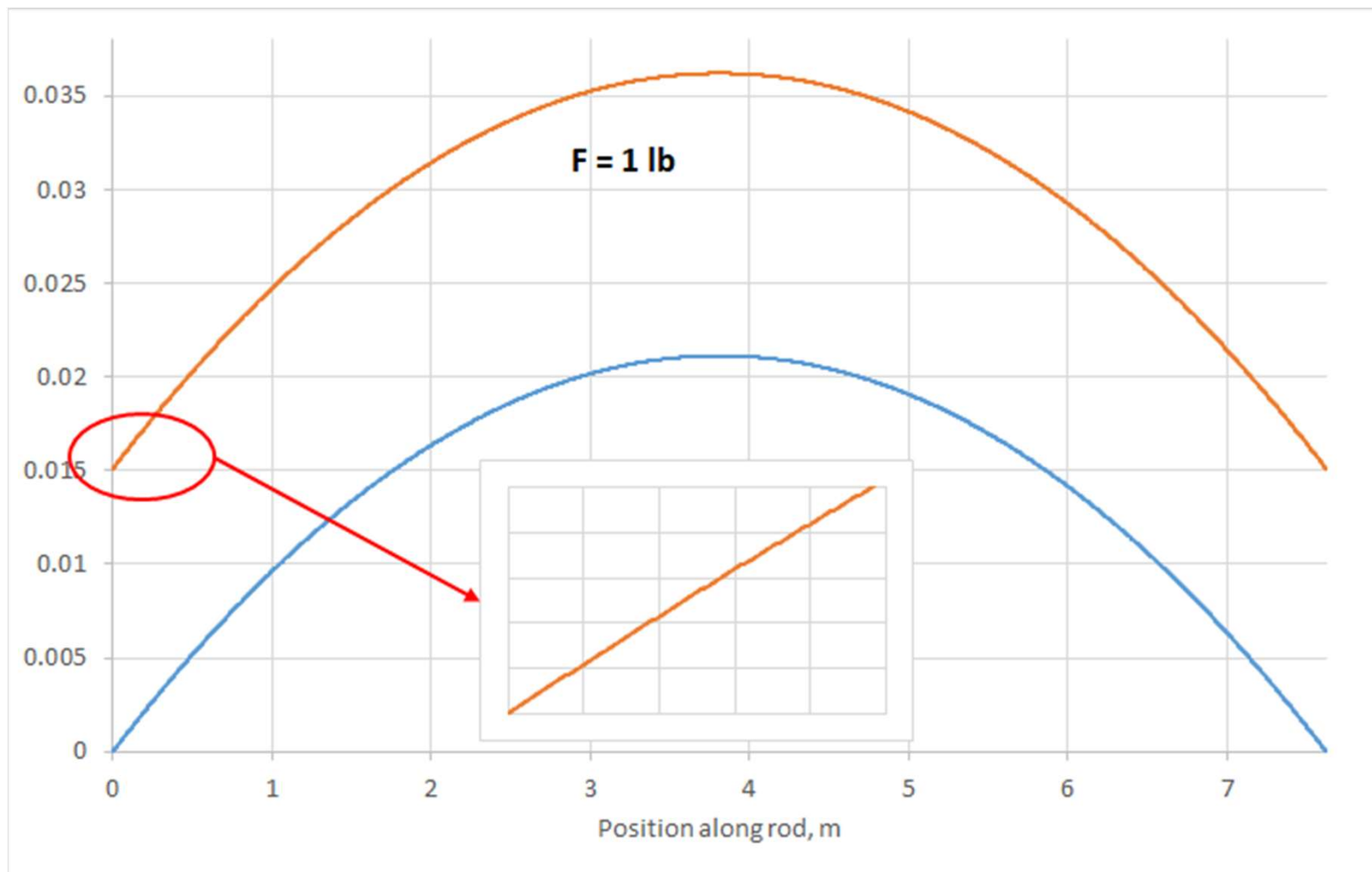
- **Effective curvature increases as:**

Tension increases

Coupling/centralizer size increases

Space between couplings (or guides) increases

## › EFFECT OF ROD TENSION



## › HOW TO INCREASE FATIGUE LIFE

- **Drill smoother wells!**

- **Reduce the upsets**

Continuous rod is highly recommended, when it is available (or hollow rod with no upsets)

Slimhole couplings

Drive rods with reduced pin sizes (e.g. 1" rods with 7/8" pins)

- **Reduce spacing between upsets**

Rod guides on rod body

Pony rods in the worst doglegs

- **Inspect used rods**

Or use only new rods

- **Corrosion inhibition**

- **Other factors (which need careful consideration):**

Pump size

Rod diameter

Rod grade

## › FATIGUE VS. WEAR

- **Most things we can do to reduce tubing wear can also help us improve fatigue life:**

- Reducing DLS (when drilling new wells)

- Continuous rod

- Smaller diameter couplings

- Rod guides

- Plastic-lined tubing (maybe)

- **However, some may not help fatigue:**

- Tubing rotators (no effect on rod fatigue life)

- Snap-on rod guides (only help with fatigue if they stay in position)

- Spin-through centralizers (may make fatigue worse due to larger upset)

## › EXAMPLES

- **Canadian Heavy Oil**

Reduced upset connections (e.g., 1" rod with 7/8" pins)

Continuous rod

- **Continuous rod in Colombia**

SPE 102744

53% of the rod failures were at the upset (42% were in the connection)

Time between rod failures increased from <100 days to ~500 days when continuous rod was used

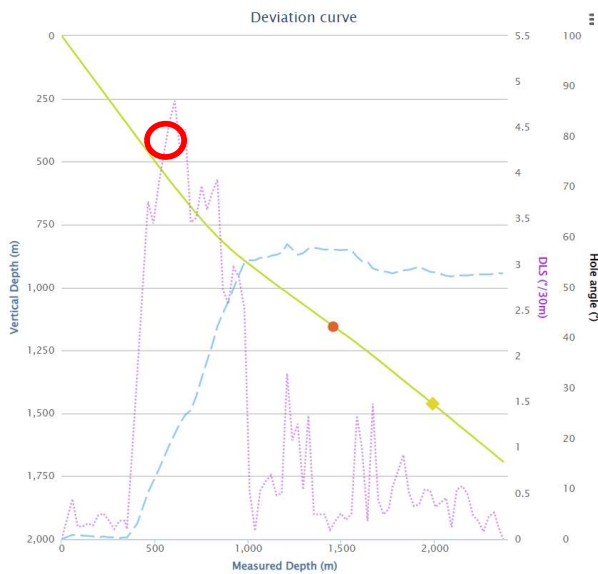
- **Modified Sucker rods in Colombia**

SPE 201146

1-1/4" rods with 1" pin -- in six test wells, five had an increased run life compared to previous design (the sixth had a tubing failure, not a rod failure)

# EXAMPLE

- PCM Failure Analysis website
- Rod failure was near to highest DLS in the well



Failure Analysis FA202000369

Operator: [redacted] Country: [redacted]  
 Field: [redacted] Well: [redacted]

PCP brand: PCM PCP model: 24E2800  
 PCP drive system: RDPCP PCP techno: PCM Moineau

Installation date: Feb 1, 2015 POOH date: Nov 10, 2020  
 Running days: 228 days Pump total runlife: 228 days  
 Reason for POOH: No Production

Stator material: 199 (Hard nit.) Stator s/n: L1V799  
 Stator manuf date: Stator condition: New  
 Stator previous run: Stator shelf life: years

Setting depth (MD): 1467 m Tubing: 3 1/2, 9.3 lbs/ft, 3"  
 Rod: SR Sim Hole 1 1/8 Well Next Step: Replace PCP...

Rotor size: W68 Rotor s/n: AV823  
 Rotor condition: New Rotor previous run:

1 PCP System 2 Rotor 3 Stator external 4 Stator bore scope 5 Stator destructive 6 Stator hardness 7 Bench test 8 Operations data 9 Others 10 Conclusions

### PCP System

Rank	System item	System observation	Comments
Rank 1 (most relevant)	Rod - Body	Broken/Fractured	Parted 73rd sucker rod (on body) due to fatigue failure
Rank 2 (less relevant)	Torque Anchor	Broken/Fractured	Broken (missing) 4 anchoring blades

General comments: Parted sucker rod N°73. Missing anchoring blades on torque anchor.

#### Specific controls

- Difficulties to POOH Rod String
- Parted Rod String
  - Distance from surface: 560 m or ft
- Rod Centralizer Above Pony Rod
  - Material: Plastic Size: 3 1/2 - 1"
- Pony Rod Above Rotor
  - Length: 8 ft Diameter: 1 1/8"
- Tubing String Leak
  - Torque Anchor Spring Test at Surface Conducted
  - Test result: Not ok

#### Photos

File #VISY1  
Distance from top: 8.17 m or ft  
Description: Torque anchor  
Comments: Failed anchoring blades

File #VISY2  
Distance from top: 8.70 m or ft  
Description: Stop bushing  
Comments: No damage on stop bushing

File #VISY3  
Distance from top: 560 m or ft  
Description: Parted rod  
Comments:

File #VISY4  
Distance from top: 560 m or ft  
Description: Observed fatigue failure on rod  
Comments:

Delete Save

PCM Failure Analysis 2020 V1.3.1

## › QUESTIONS?

- **Contact:** [pskoczylas@pcmals.com](mailto:pskoczylas@pcmals.com)

- **References:**

“Drive String Fatigue in PCP Applications”, SPE 171352, by Paul Skoczylas, 2014.

“Improvement of the Well Intervention Index by the Implementation of Alternative Conventional Rod with Modified Pin in Artificial Lift Systems with Progressive Cavity Pumps Systems in Deviated Wells”, SPE 201146, by Laura Labrador et al, 2020.

“Decreasing Well Downtime in Guando Oil Field by Using Continuous Sucker Rod”, SPE 102744, by H. Ariza et al, 2006