keep it moving

PCP ROD STRING FATIGUE

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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

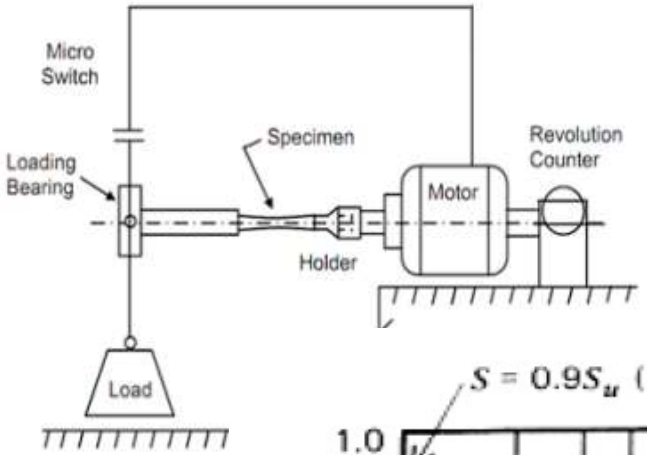
WHAT IS FATIGUE?

- **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.**

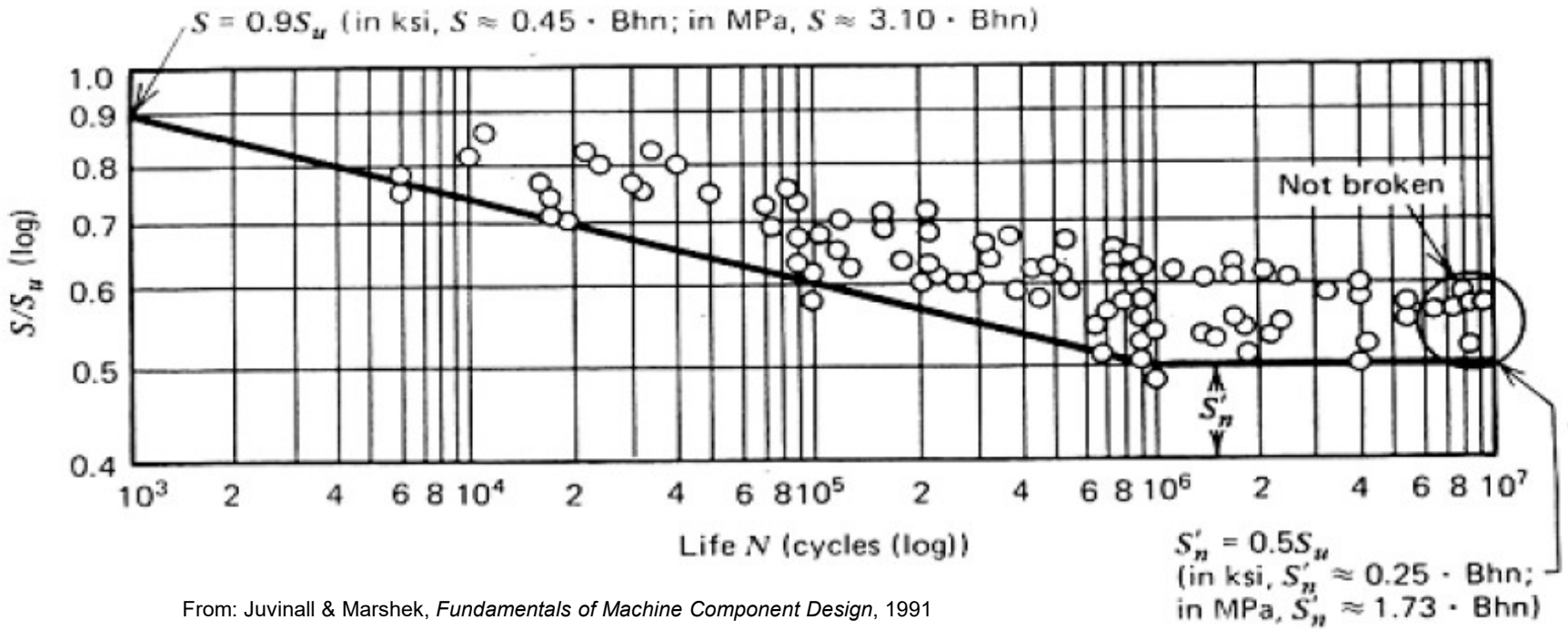
  This bending stress is usually quite small relative to the stress from torque and tension, but over millions of cycles, it can lead to fatigue failures

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

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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**

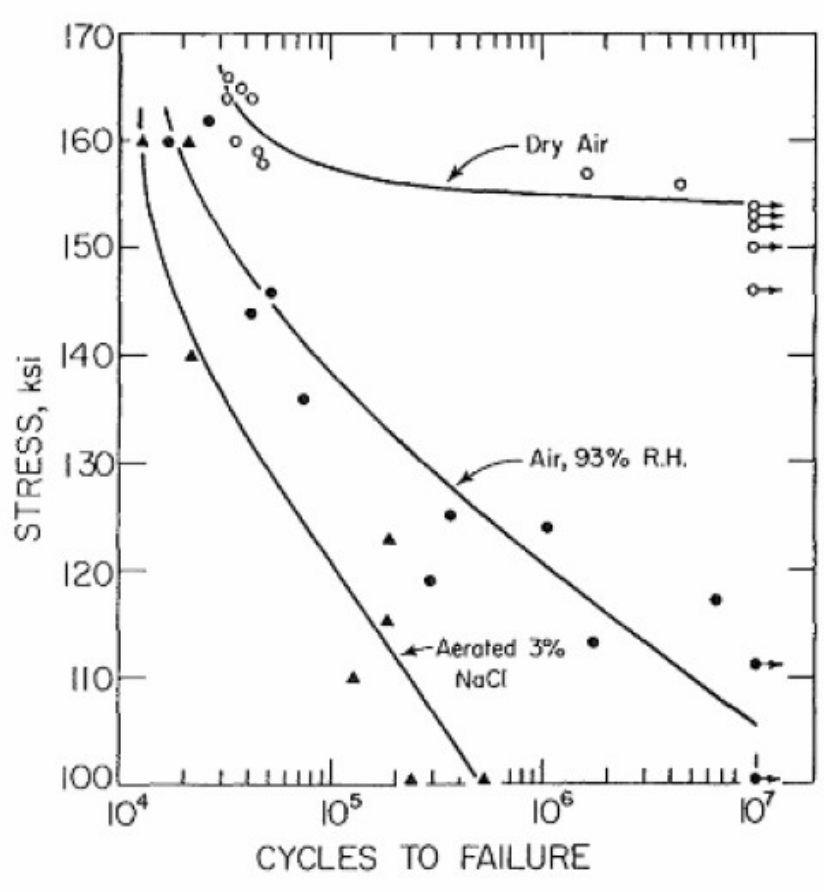
  Not directly applicable to PCP applications

  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

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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

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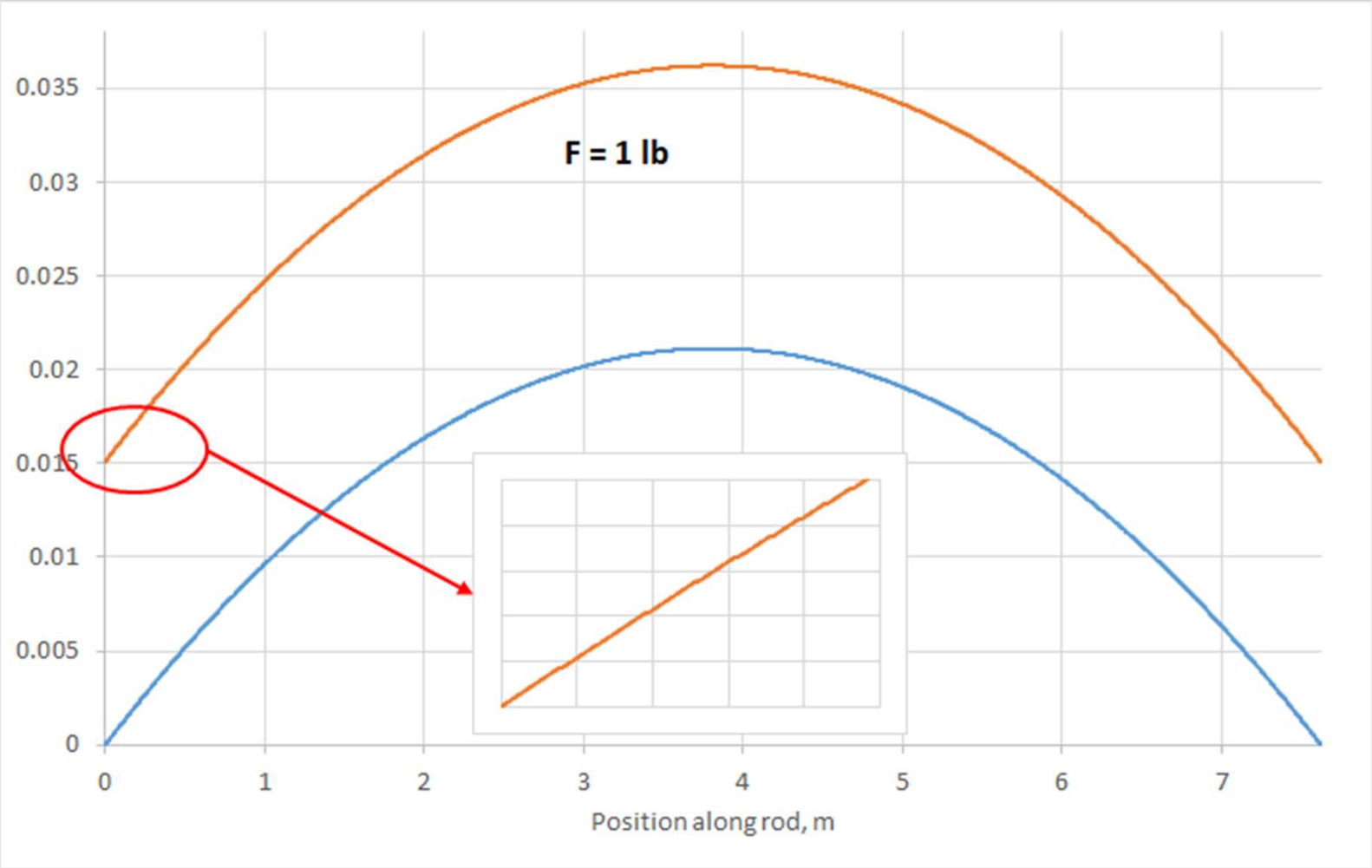
EFFECT OF ROD TENSION



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

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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

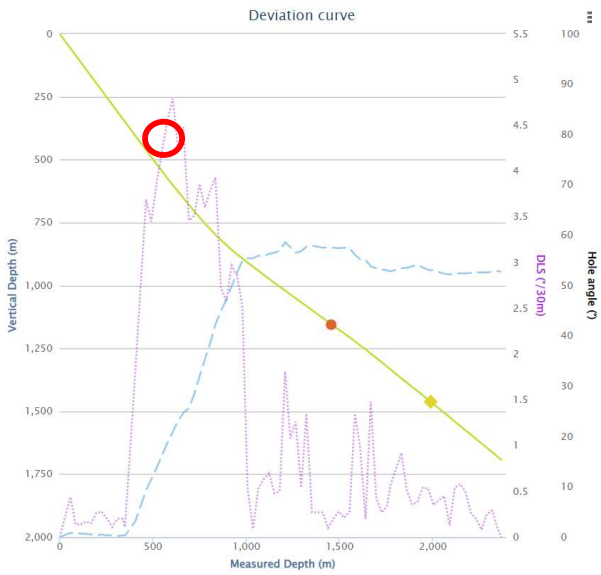
- **Modified Sucker rods in Colombia**

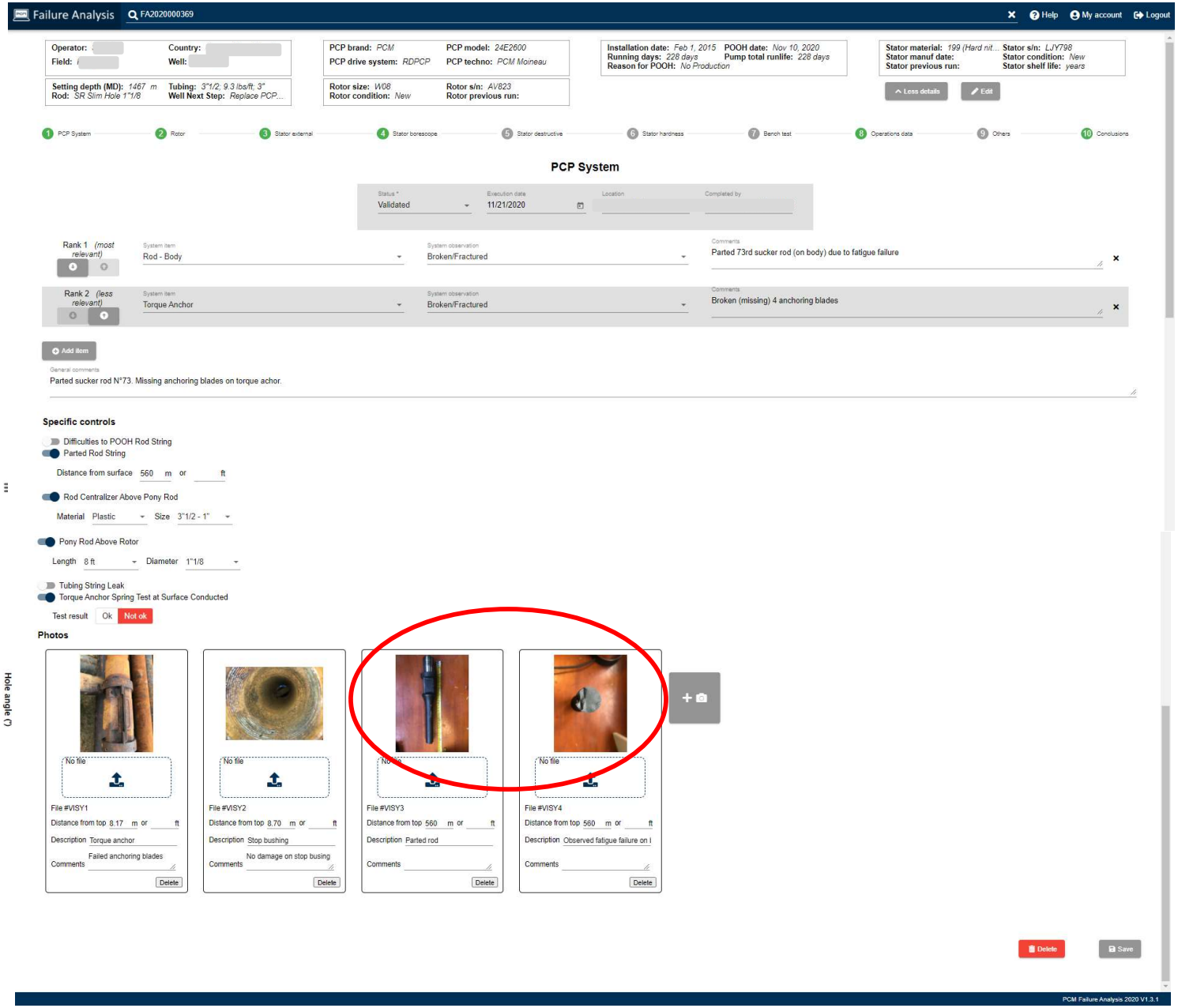
  SPE 201146

  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**





QUESTIONS?

- **Contact:** 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