Unaccounted Sources of Friction that Lead to Sticking and Other Problems

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(((ECHOMETER)))
Introduction

• Damping Coefficients used to Subtract out Losses from the Surface Horsepower using the Wave Equation Down the Rod String as a Function of Velocity

• Excess Unaccounted Friction Shows up in the Pump Card Loads:
  1) Pump Card loads higher than Expected.
  2) Pump card down stroke loads normally should set on the ZERO load line & approach Fo from Fluid Level
  3) Pump loads outside this range indicate friction unaccounted by the wave equation.
Pump Card Rests on Zero Load Line on Down Stroke. Pump Card Near Fo From Fluid Level on Up Stroke.

Calculated Pump Card Loads:
SV Open Upstroke:
\[ \text{Fo Max} = (P_{\text{dis}} - 0) \times Ap \]
\[ \text{Fo} = (P_{\text{dis}} - P_{\text{intk}}) \times Ap \]

TV Open Downstroke:
\[ \text{Fo} = 0 \]

Pump Card Reference Lines:
1. **Fo Max** - assumes pump intake pressure is zero, where well provides no help in lifting the fluid to the surface.
2. **Fo From Fluid Level** - assumes pump intake pressure determined from fluid level shot, where well's PIP provides help in lifting the fluid.
3. **Zero Load Line** - assumes pressure above and below the plunger are equal; no friction due to fluid displacing through SV on down stroke

Fluid Load Lifted by Rods
- Well ~ Height of Pump Card
- Fluid Load Lifted by Rods

Surface Card

Fo loads measured Dynamometer or calculated From Fluid Level.
Damping

1. Unaccounted friction impacts shape of pump card; friction increases load range.
2. “Unaccounted” is extra friction not removed by the wave equation calculating pump card.
3. Damping coefficients subtract “friction” from rods as function of velocity.
4. Change damping coefficients from the default to “Sort of” account for friction.
5. Wells having shallow depth with out much deviation; damping coefficients are usually 0.01/1000 feet of depth. Use 0.01/2000 feet for pump depths greater than 5000 feet.
6. Increase damping as the downhole fiction goes up
7. Decrease damping as the well gets shallower.
1. Polish Rod HP Minus Damping Equals Pump HP.

2. Polish Rod Horsepower less frictional horsepower equals the hydraulic horsepower, and represents work being done at the pump.
Adjusting Damping Coefficients

When the pump load lines B - C and D - A are nearly flat then the proper amount of damping has been added.

- Zero damping
- OK damping
- Too much damping

Concave in and the damping coefficient are too high
Damping Coefficients for Viscous Crude

0.05 Default Damping
NOT Enough

Damping = 0.22
OK

Pump Depth = 8892 ft

330 BOPD 37 BWPD
10 Deg API Gravity
Damping Coefficients for Shallow Wells are usually 0.01/1000 foot of Pump Depth

For many wells the 0.05 default damping usually OK

Manually decrease damping as the well gets shallower.

Damping = 0.029

Pump Depth = 2916 ft
Abnormal Loads – Tight Stuffing Box

Normal

HP = 6.0

15% Higher HP

Too Tight

HP = 9.2

HP = 7.3
1. Pump card should fall below the FoMax line and rest on the Zero load line.

2. Restricted Discharge Area Resist Flow of Fluid out of the Pump (for example if the plunger area is greater than the area between the tubing and rods, then the pump must apply extra pressure to the fluid above the required discharge pressure)

3. Extra pressure inside pump barrel results in additional fluid load on the rods from the plunger; then the pump card Fo line can go above FoMax.

Damping Coefficients for Bottled up Pump

- 0.05 Default Damping OK
- 3.75 Pdia ~ 2.875 Tubing
- 5 BOPD 600 BWPD
- 40 Deg API Gravity
- Pump Depth = 1870 ft
1) Diagnostic dynamometer surface cards used for Diagnosing Sucker Rod Pumping Systems.

2) Pump dynamometer card is to identify and analyze downhole problems.

3) Spike load at 100.2 inches on Stroke #1 shows when the plunger stopped on the upstroke. Unusual shape occurs over a 0.6 second time period and represents 4280 lb load increase required to overcome the downhole friction.
Polished Rod Moves up 20” to Apply 4280 Lbs Spring Force

\[ F = Kr \times X \]

\[ Kr = 214 \text{ Lb/in} \]

\[ F = 214 \times 20 = 4280 \text{ Lbs} \]

Plunger Position MUST be Flat OR Not Sticking!
Polished Rod Moves up 20” While Plunger Stopped 0.6 Sec.

Plunger Stops for 0.6 Seconds while Polished Rod moves up 20 inches. Applying a 4820 Lb Force, before plunger starts to move.

When no longer Stuck Plunger Moves Quickly at Top of Stroke
Sticking Sudden Release Moves Plunger 33.5” w/Polished Rod at top of Stroke

134.6”

101.1”
Plunger Stuck 0.6 Sec., Moves 33.5” in 1.1 Seconds After Unstuck

Plunger Stuck 0.6 Sec
Velocity Goes to Zero

33.5”
Unstuck
Drop in Surface Load Occurs When Plunger Becomes Unstuck and Moves

PR Load Drops when Unstuck
Plunger Moves Quickly
At Surface Polished Rod Moves up 20” with a Corresponding 6.53 KLbs Force

120”

140”

25.59 KLbs

19.03 KLbs
W/ Little Change in PR Position
Polished Rod Load Drops 9.56 KLbs

Polished Rod Position (In) vs. Polished Rod Load (KLbs) vs. Elapsed Time (Sec)
Excess Well Bore Friction: Friction Affects Dynamometer Cards

Fo Upstroke too High
Fo Downstroke too Low
Excess Well Bore Friction:
Unaccounted Friction shows up in Pump Card

Possible Sources:
1. Paraffin
2. Scale
3. Over Tight Stuffing Box
4. Misalignment
5. Deviated Well
6. Pump Friction
7. Crimped Tubing
8. Other

Fo = (P_{dis} - P_{intk}) \times Ap

Pump card has calculated loads much higher than the Fluid Load based on a shot Fluid Level.
Excess Well Bore Friction: Reduced Downhole Stroke & Raised Fluid Level
Excess Well Bore Friction: Friction Impacts Valve Load Test

TV Load too High

SV Load too Low
Ignore Unaccounted Wellbore Friction

PIP = 18

PIP = 330

PIP = 341
Excess Well Bore Friction Indicators

1) Fluid Level is higher than normal
2) Surface card shows a vertical change in load at the top and bottom of the stroke (Extra friction opposite to the direction of movement is broken by changing the direction of motion)
3) Pump card should set between the ZERO load line & Fo Max, pump loads outside this range indicate of unaccounted friction.
4) SV valve check is low and TV check is too high (Friction is resisting the lifting the rods on the upstroke and friction is holding rod load on the downstroke)
5) TV load immediately drops as brake released (When the direction of motion changes or the rods go from stopped to moving the friction force that was being applied opposite to the prior motion of the rods is broken).
6) Low system efficiency
Investigation of Well Problem:
83% of Surface Stroke lost to Rod Stretch
After Hot Water Treatment +100 BPD
Observations

• Pump card normally should set between the ZERO load line & Fo Max, pump loads outside this range indicate friction unaccounted for by wave equation.

• DO NOT HAVE TO CHANGE DAMPING; just note that downhole friction is high and PIP from Pump Card too LOW!!!

• May need to Adjust PIP from Pump Card.

• If treatment for Downhole Friction is Effective, then horsepower should go down and pump card should reflect improvement.
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