System Design & Diagnostic Analysis of Group 2 Systems

John G. Svinos – President
Theta Oilfield Services, Inc.
www.gotheta.com
Rod Pumping Systems may look the same, but they are not

- Group 1 Rod Pumping Systems:
  - Pump depth > 4000' & any plunger size
  - Pump depth < 4000' & plunger <= 2.00"

Well documented group. Pump dynamometer card shapes depend only on pump condition.
Shallow Higher Rate Wells are Different

- Group 2 Rod Pumping Systems:
  - Pump depth < 4000' & with pump plunger of 2.25 inches or larger.

Pump dynamometer card shapes depend on: pump condition, pump depth, tubing size, plunger size, fluid compressibility, pumping speed, and other variables.
Basic Functions of Wave Equation Diagnostic Computer Programs:

• Input:
  – Measured dynamometer card
  – Pumping speed (SPM)
  – Pump size
  – Rod string design
  – Pumping unit type and size
Basic Functions of Wave Equation Diagnostic Computer Programs:

• **Output:**
  - Peak & min. polished rod loads
  - Rod stresses and rod loading
  - Gearbox loading
  - CB moment to balance unit
  - System efficiency
  - Downhole pump dynamometer card
Downhole pump card shapes for Group 1 Systems depend only on pump condition

- Full pump anchored tubing
- Fluid pound anchored tubing
- Severe fluid pound anchored tubing
- Completely pumped off Anchored tubing
- Leaking traveling valve or plunger
- Full pump unanchored tubing
- Fluid pound unanchored tubing
- Severe fluid pound unanchored tubing
- Malfunctioning tubing anchor
- Leaking standing valve
Downhole pump card shapes for Group 1 Systems are easier to Interpret

- Full pump hitting Down
- Full pump hitting Up
- Gas locked pump
- Gas interference
- Bent of sticking pump barrel
- Worn or split pump barrel
- Slightly worn pump
- Worn out pump
- Severely worn out pump or parted rods
- Severe traveling valve leak
Group 1 vs Group 2 fluid load shock absorption on the apstroke

- Rod string stretch (main shock absorption)
- Fluid compressibility (minor shock absorption)
Group 2 Wells are Different Because of Fluid Inertia Effects

Because of the dependence of the downhole pump dynamometer card shapes on fluid inertia effects in Group 2 wells, the library of shapes for Group 1 wells cannot be used to analyze the pump condition of Group 2 wells.
Effect of Fluid Inertia effects on downhole dynamometer card shape

Downhole pump card without Fluid Inertia Effects (Group 1)

Initial Pressure wave

Pressure wave reflection

Downhole pump card with Fluid Inertia Effects (Group 2)

Static Fluid Load
Field Verification Using Downhole Pulsation Dampener

From SPE 18779
Bladder N₂ pressure set to tubing hydrostatic pressure
Before and after surface dyno cards
Before and after downwhole cards

![Graph showing load versus position with and without dampener](image-url)
Group 2 System Computer Simulation is Now Possible

To accurately simulate fluid inertia effects

You need two wave equations solved simultaneously:

• Wave Equation for stress waves in rods
• And Wave Equation for pressure waves in tubing
• In Group 2 Wells, fluid compressibility makes a difference, so the correct fluid compressibility must be used.
Group 2 System, Example 1

- Pump depth: 500' - 2500'
- Fluid level: 100' over pump
- Rod string: API 77, grade D
- Plunger diameter: 2.75''
- Fluid Compressibility: 2.0
- Pumping Unit: C-228-173-100
- Stroke length: 103''
- Pumping speed: 12 spm
Effect of Pump Depth on Dyno Shape

Surface

Dowhole

500 ft

1000 ft

1500 ft

2500 ft
Group 2 System, Example 2

- Pump depth: 1500'
- Fluid level: 100' over pump
- Rod string: API 66, grade D
- Plunger diameter: 2.75"
- Fluid Compressibility: 2.0
- Pumping Unit: C-228-173-100
- Stroke length: 103"
- Pumping speed: 8 - 14 spm
Effect of Pumping Speed on Dyno Shape

Surface

SPM=8

SPM=10

SPM=12

SPM=14

Dowhole
Group 2 System, Example 3

- Pump depth: 1500'
- Fluid level: 100' over pump
- Rod string: API 66, grade D
- Plunger diameter: 2.25” to 3.75”
- Fluid Compressibility: 2.0
- Pumping Unit: C-228-173-100
- Stroke length: 103"
- Pumping speed: 12 spm
Effect of Pumping Speed on Dyno Shape

Surface

Dp=2.25"

Dp=2.75"

Dp=3.25"

Dp=3.75"

Dowhole
To Correctly diagnose Group rod pumping systems:

1) Analyze surface dyno with wave equation diagnostic software.

2) Simulate system with 2-Wave equation (fluid inertia) predictive software.

3) Compare predicted vs measured dynos

4) If there is a good match then there is no problem with the pump.

5) If there is not a good match, then a problem exists.

6) Or use Expert Diagnostic software that can automatically diagnose Group 2 Systems using pattern recognition and enhanced Group 2 analysis.
EXPERT DIAGNOSTIC ANALYSIS REPORT

DOWNHOLE EQUIPMENT ANALYSIS
The pump is full and is in good mechanical condition. The downhole pump card shows fluid inertia effects, which are normal for the well conditions you specified.

ROD STRING ANALYSIS
The rod string is not overloaded.

SURFACE EQUIPMENT ANALYSIS
The gearbox is not overloaded; however, the pumping unit is severely out of balance. Balancing the unit for minimum torque will lower the gearbox loading to 30%. You can reduce electricity costs by $144 per month by balancing the unit for minimum energy consumption.

The structure of the pumping unit is not overloaded.
Modern Expert Diagnostic Software “Knows” about Fluid Inertia Effects
EXPERT DIAGNOSTIC ANALYSIS REPORT

DOWNHOLE EQUIPMENT ANALYSIS
There is a slight traveling valve or plunger leak. The pump barrel may be bent, or the plunger may be sticking. There are 2.2 inches of tubing movement. The downhole pump card shows fluid inertia effects, which are normal for the well conditions you specified. XDIAG has determined the fluid level to be 1180 feet from surface (829 FOP), which corresponds to a pump intake pressure of 368.9 psi.

Due to the downhole pump condition, the pump friction could not be reliably estimated.

ROD STRING ANALYSIS
The rod string is not overloaded.

SURFACE EQUIPMENT ANALYSIS
The gearbox is 19% overloaded. The pumping unit is slightly out of balance. The gearbox is undersized, since it would be overloaded by 12% even after balancing the unit for minimum torque.

The structure of the pumping unit is 92% loaded.

INPUT DATA ANALYSIS
The load cell appears to be reading high by 554 lbs. This load shift was corrected.
Modern Expert Diagnostic Software “Knows” about Fluid Inertia Effects
Group 2 System design is very important to avoid equipment overload. Group 2 Systems must be designed with fluid inertia modeled correctly. Otherwise:

- Pumping unit gearbox can be overloaded.
- Rods can be overloaded.
- Prime mover may be undersized.
- Other important system parameters may be incorrect and wrong system designs can be used.
Measured surface and downhole dynos for pulsation dampener test well
Predictive surface and downhole dynos for pulsation dampener test well
Predictive vs measured surface dynos with two wave equation modeling
Predictive surface dyno with conventional single wave equation
Examples of Predicted vs Measured Dynos for Group 2 Wells

Dynamometer Cards

Dynamometer Cards

Dynamometer Cards

Dynamometer Cards
Examples of Predicted vs Measured Dynos for Group 2 Wells
Conclusions

1) Rod pumping wells must be divided in two groups (Group 1 and Group 2) to avoid diagnostic and design problems.

2) Group 2 systems are significantly affected by fluid inertia effects.

3) Conventional wave equation software can be used to analyze Group 1 or Group 2 systems but pump condition diagnosis is very difficult.

4) Expert (AI) diagnostic software with enhanced group 2 analysis capabilities can be used to correctly diagnose the pump condition of Group 2 Systems.

5) Enhanced Two-Wave Equation predictive software with fluid inertia effect modeling is needed to accurately simulate Group 2 systems.
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