TOTAL DOWNSTROKE FRICTION FROM DOWNHOLE DYNAMOMETER ANALYSIS

Scott W. Long, P.E., SPE
Flexbar, Inc.

Elton Smith, SPE
Kirk Mehaffey
Albert Garza
Pioneer Natural Resources, USA, Inc.

Abstract

The Oil and Gas Industry is benefiting from development and use of improved predictive computer programs that now utilize several friction defaults.

These predictive programs are more capable of predicting surface and downhole rod pumping conditions. The need for improved predictive accuracy is requiring program users to adopt improved estimates of downstroke friction to model downhole pumping conditions. Lack of improved estimates of downstroke friction has resulted in program users accepting and designing with current friction defaults that may result in results different than actual downhole pumping conditions.

This paper develops a method of estimating total downstroke friction from existing dynamometer analysis. Use of this method in producing fields with similar operating conditions will provide improved estimates of total downstroke friction.

A better understanding of the magnitude of total downstroke friction will result in improved friction defaults. Improved friction defaults will result in more effective designs of rodstrings and artificial lift systems.

Purpose

This paper will present a method of estimating total downstroke friction that includes the following;

1. Measuring total downstroke friction from existing Dynamometer Analysis.
2. Selecting Dynamometer Analysis representing full downhole cards.
3. Utilizing existing Dynamometer Analysis from producing leases.
4. Resulting in improved total downstroke friction estimates more representative of specific leases and producing operations.

Definition of Total Downstroke Friction

Total downstroke friction is the sum of four (4) friction components. These components are as follows;

1. Stuffing Box Friction
2. Rod-on-Tubing Friction
3. Dynamic Fluid Friction
4. Mechanical Pump Friction

Summary of Current Friction Defaults

Current predictive computer programs utilize several defaults to estimate total downstroke friction. Listed below are some of the current defaults that would be utilized for a producing well with a seating nipple depth of 8000 feet. This seating nipple depth is representative of wells in this paper.

		Default
Stuffing Box Friction		100 Lb.
Up & Downstroke Rod-on-Tubing Friction		400 Lb.
Dynamic Fluid Friction		??? Lb.
Mechanical Pump Friction		200 Lb.
Total Downstroke Friction	Greater than	700 Lb.

Discussion of Current Friction Defaults

Stuffing Box Friction

Stuffing box friction is developed by movement of the polished rod through the stuffing box rubbers. This friction component can be as large as 2000 Lb. depending on type, installation and maintenance of the stuffing box. This friction component occurs only in the stuffing box and the impact on total downstroke friction should be negligible, unless the estimated stuffing box friction default is less than the actual stuffing box friction. In this case, this excess friction may be transferred to the pump.

Rod-on-Tubing Friction

Rod-on-Tubing friction is created by rodstring contact with production tubing during the upstroke and downstroke. To estimate this default for the downstroke portion of the pumping cycle, 5 % of the seating nipple depth was utilized. The downstroke is analyzed in this paper because it is during this part of the pumping cycle when downstroke compression may cause rodstring buckling.

Dynamic Fluid Friction

Dynamic fluid friction is friction developed from movement of fluid around sucker rod body, couplings and production tubing. This friction component is dependent on fluid velocity, fluid viscosity, water-oil ratio, fluid temperature and other variables. Dynamic Fluid Friction, at this time is difficult to estimate.

Mechanical Pump Friction

Mechanical **pump** friction is the friction developed from metal-on-metal contact and fluid movement through downhole pump components. Variables such as plunger size, plunger speed, plunger-barrel clearance, plunger length and barrel flexing increasing barrel-on-plunger contact may impact this friction component. Studies are underway to model these pump parameters to better estimate pump friction.

Discussion

Use of the four (4) friction defaults to estimate downstroke friction will result in total downstroke friction estimates in excess of 700 Lb. Comparison of these friction defaults and their relative magnitude indicate that the most significant default(s) contributing to total downstroke friction may be Rod-on-Tubing Friction and Mechanical Pump Friction.

Utilizing Downhole Dynamometer Analysis

This paper established 700 Lb. as total downstroke friction and used it as a benchmark. This benchmark was compared to the total downstroke friction measured from dynamometer analysis. The result of this comparison was adjustments to the four (4) friction defaults providing predictive designs more representative to the specific leases and their downhole producing conditions.

Selected Producing Leases

Two (2) different leases were selected for this paper. Existing Dynamometer Analysis were collected from both leases to estimate and compare to our 700# benchmark. A description of these leases is listed below. The Shackleford Sprabeny Unit is identified as SSU and leases not in this unit are identified as Non-SSU.

Description of Selected Producing Leases

Lease Name	Non-SSU	SSU
Field Name	Sprabeny	Sprabeny
County	Midland and Martin	Midland
Average Seating Nipple Depth	7,804 feet	7,094 feet
Producing Age of Field	Greater than 5 years	Less than 5 years
Average Tubing Gradient (psi / foot)	0.40 psi / foot	0.41 psi / foot
Total Number of Dynamometer Analysis	254	164

Description of Selected Field Operations

Lease Name	Non-SSU	SSU
Plunger Diameter	1.063” and 1.25”	1.25” and 1.50”
Average Polished Rod Velocity	988 inches / minute	1,346 inches / minute
Average Strokes per Minute	6.5 strokes / minute	8.1 strokes / minute
Average Stroke Length	76.8 inch	83.3 inch
Pumping Units	Conventional	Conventional

Calculation of Total Downstroke Friction

Total downstroke friction was calculated for each of the 254 Non-SSU and 164 SSU Dynamometer Analysis. For each calculation, the buoyant force (Lb.) at the bottom of the rod string was subtracted from the bottom minimum load (Lb.). The resulting load was total downstroke friction (Lb.).

Total Downstroke Friction (Lb.) = (Bottom Minimum Load (Lb.) – Buoyant Force (Lb.) at Bottom of the Rod String)

Calculation of Average Polished Rod Velocity

For each calculated total downstroke friction, an average polished rod velocity was calculated.

Average Polished Rod Velocity (inches / minute) = (2) X (Strokes / Minute) X (Measured Stroke Length (inches))

Plotting of Total Downstroke Friction vs. Average Polished Rod Velocity

Total downstroke friction was plotted against average polished rod velocity for Non-SSU Spraberry lease data and **SSU** Spraberry lease data. All data was plotted by plunger diameter.

Full downhole pump cards were utilized to avoid excessive downstroke friction that might be developed from excessive fluid pound or gas interference due to incomplete pump fillage.

Graph 1 represents the Non-SSU lease data with 1.063" and 1.25" diameter plungers.

Graph 2 represents the **SSU** lease data with 1.25" and 1.50" diameter plungers.

Results

Graph 1
Non-SSU Lease Data
from Full Pump Cards

Plunger Diameter	No. of Data Points	Average Polished Rod Velocity	Total Downstroke Friction at Average Polished Rod Velocity	Average Pump Clearance
1.063 inch	(20)	945 inches / minute	790 Lb.	0.0029 inch
1.250 inch	**(234)**	992 inches / minute	926 Lb.	0.0035 inch

Graph 2
SSU Lease Data
from Full Pump Cards

Plunger Diameter	No. of Data Points	Average Polished Rod Velocity	Total Downstroke Friction at Average Polished Rod Velocity	Average Pump Clearance
1.250 inch	(133)	1,313 inches / minute	,492 Lb.	0.0035 inch
1.500 inch	(31)	1,486 inches / minute	,544 Lb.	0.0035 inch

Comparison of Total Downstroke Friction to Benchmark Default of 700 Lb.
Results of data represent a range of total downstroke friction from 790 - 1,544 Lb. Average total downstroke friction is 1,118 Lb.

	Plunger Diameter	Average Polished Rod Velocity	Total Downstroke Friction from Full Pump Cards	Total Downstoke Friction Greater Than 700 Lb.
Non-SSU Data	1.063 inch.	945 inches / min.	790 Lb.	90 Lb.
	1.250 inch.	992 inches / min.	926 Lb.	226 Lb.
SSU Data	1.250 inch.	1,313 inches / min.	1,492 Lb.	792 Lb.
	1.500 inch.	1,486 inches / min.	1,544 Lb.	844 Lb.
		Average	1,188 Lb.	488 Lb.

Comparing the average of total downstroke friction to the total downstroke friction benchmark default of 700 Lb. resulted in a range of additional downstroke friction from 90 - 844 Lb. Average additional downstroke friction is 488 Lb. This additional downstroke friction represents a 70 % increase in total downstroke friction as compared to the total predictive friction benchmark default of 700 Lb.

Conclusions
Use of current friction defaults resulted in estimates of total downstroke friction 90 - 488 Lb. less than total downstroke friction measured from downhole dynamometer analysis.

Distribution of this additional 90 - 488 Lb. of downstroke friction to the four (4) friction components will provide a more representative estimate of total downstoke friction.

The most appropriate distribution of this 90 - 488 Lb. of additional downstoke friction may be to the rod-on-tubing friction and / or mechanical pump friction defaults.

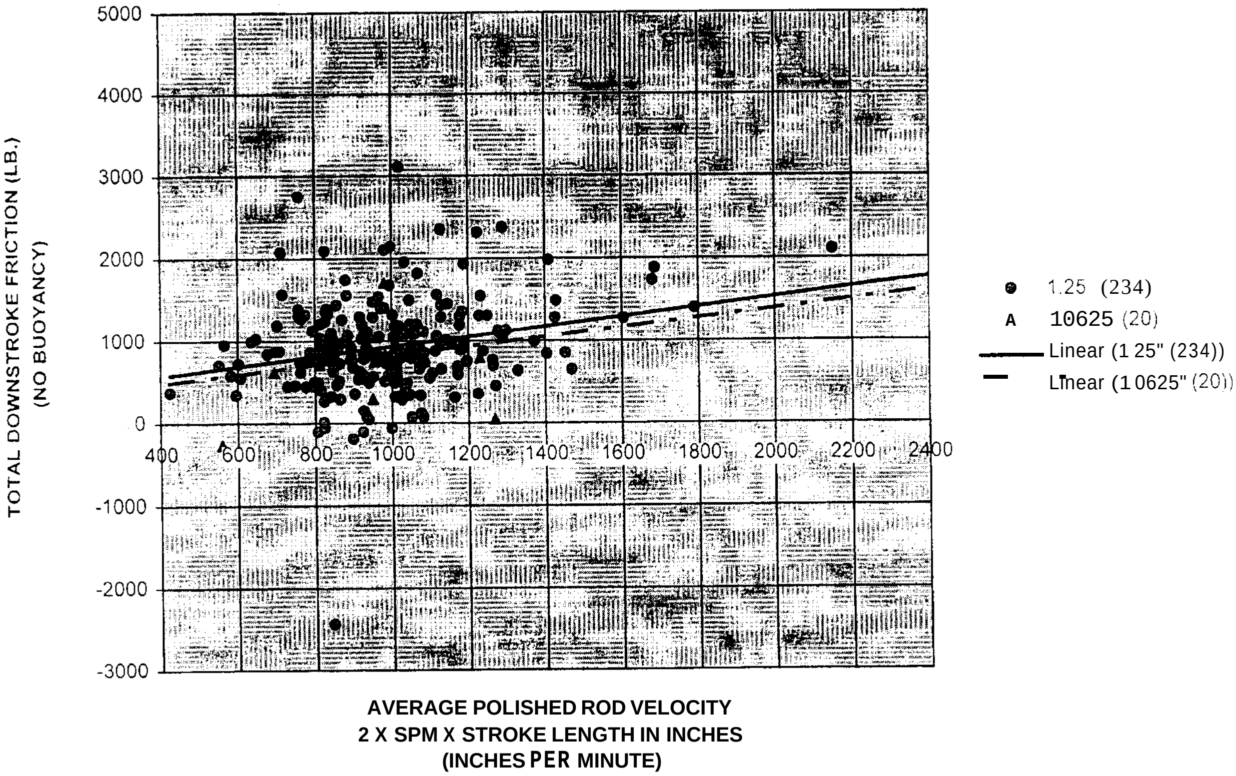
Total downstroke friction increases with increasing plunger diameter and average polished velocity.

Use of inaccurate load cells will have **a** significant impact on the results from Dynamometer Analysis.

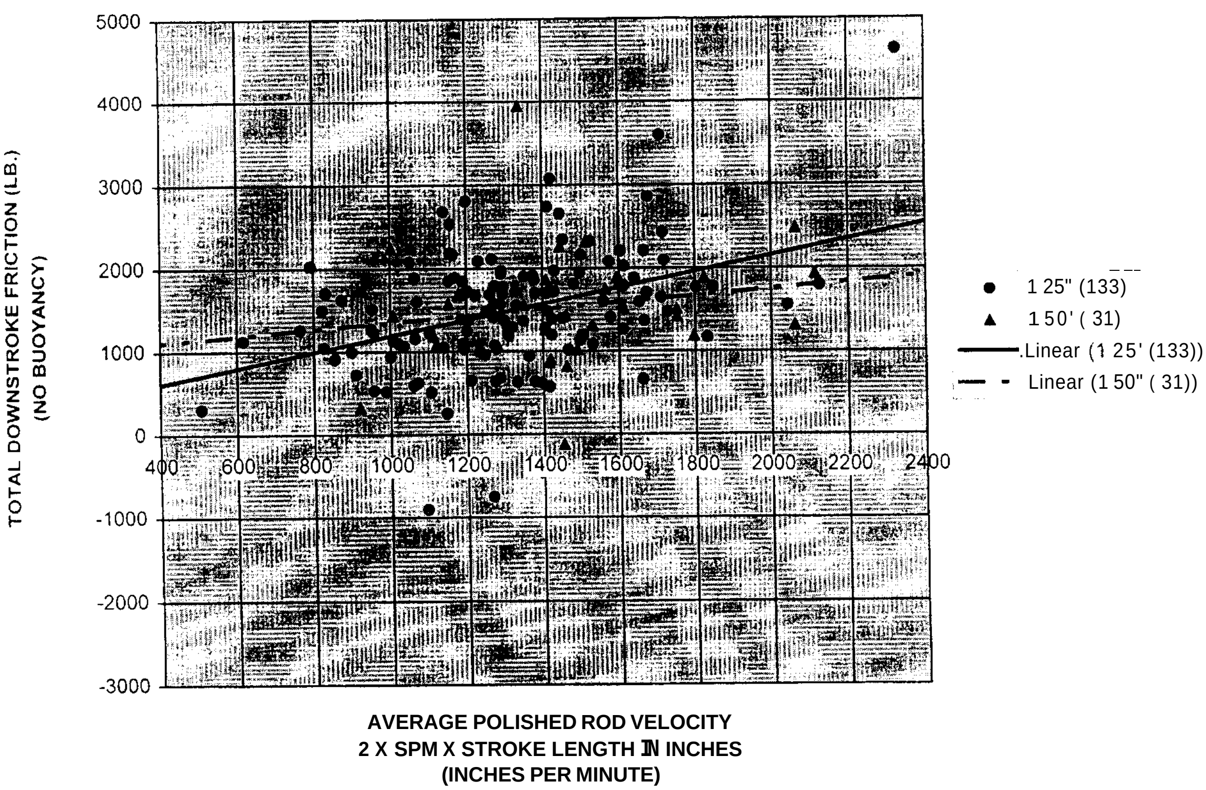
Use of pattern recognition software for downhole pump cards may provide improved estimates of mechanical pump friction.

Contributors

Pioneer Natural Resources USA, Incorporated		Midland, Texas
Mr. Fred Morrow,	Lufkin Automation, Incorporated	Midland, Texas
Mr. Ken B. Nolan,	Lufkin Automation, Incorporated	Midland, Texas
Mr. John G. Svinos,	Theta Enterprises, Incorporated	Brea, California
Mr. Jim V. Curfew,	Arco-Permian	Midland, Texas
Mr. John C. Patterson,	British Petroleum	Plano, Texas
Mr. Donald W. Bennett,	Flexbar, Incorporated	Midland and Odessa, Texas
Mr. Johnny Bunsen	Tommy White Supply Company	Midland, Texas



Graph 1 - Total Downstroke Friction vs. Average Polished Rod Velocity
Pioneer Natural Resources, *Non*-Shackleford SPRA. Unit Wells



Graph 2 - Total Downstroke Friction vs. Average Polished Rod Velocity
Pioneer Natural Resources, Shackleford Spraberry Unit (*SSU*)