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Rod String Dynamics

Controlling the surface motion profile to minimize sucker-rod dynamics



Pump/Rod Selection

A convenient pump and rod selection guide is now available online



Solar-Powered RPC

Sophisticated rod pump controller operates using solar energy



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Technically Speaking



Using Surface Motion Profiling to Manage Sucker-Rod Dynamics

by Ron Peterson *development engineer*

One aspect of sucker-rod-pumped wells that has vexed engineers for decades is rod dynamics—the overshoots and oscillations in rod loads that occur from acceleration forces associated with reciprocating the rod-string mass. Sucker-rod dynamics often contribute to problems such as premature rod breaks, rod fatigue, and tubing wear caused by rod buckling.

Developments over the years have adapted equipment to better tolerate rod dynamics, including more sophisticated rod string design and better rod and coupler materials. Little work has been done, however, to address the major contributor of excessive rod dynamics—the motion profile of the surface pumping equipment.

The motion profile of a conventional pumping unit is forever fixed by its geometry and speed, irrespective of rod characteristics such as stiffness, natural oscillation frequency, and natural damping. Consequently, the default conventional surface motion profile may or may not be well suited for adequate control of a given rod string. Typically it is not, as it is indifferent to the rod and pump motion, exciting rod string resonances, and undesirable dynamic loads.



The application of servo motion profiling and closed-loop damping algorithms to manage resonant loads in various machine operations has been well accepted in industrial processes for decades. The same technology can be applied to sucker rod



1 Linear Rod Pump

pumping.

To demonstrate the effect, a newer style surface linear rod pumping unit mechanism has been simulated, such as that shown in Figure 1. The linear rod pump is fitted with a variable-speed drive. As a comparison, a conventional

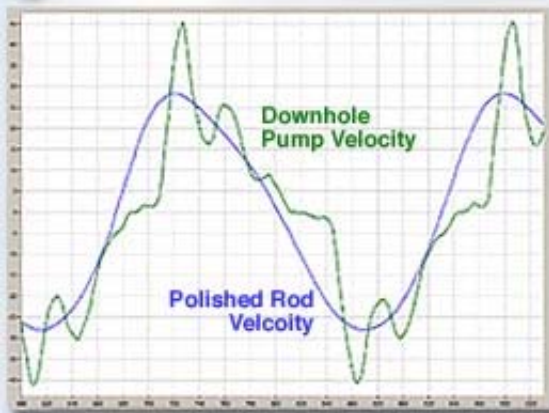
Class I pumping unit of identical stroke length and average pumping speed has also been simulated. The simulation models reservoir inflow, pump action, rod string behavior, surface pumping equipment, and motor/drive response using industry-accepted predictive software modeling techniques.

In both cases, the pump stroke is 100 inches. The examples are both running an average speed of 6 spm. The well is 5,000 feet deep with a 1.5 inch pump. The rod string is tapered with a diameter of 0.875 inches at 4,000 feet and 0.75 inches at 2,000 feet.

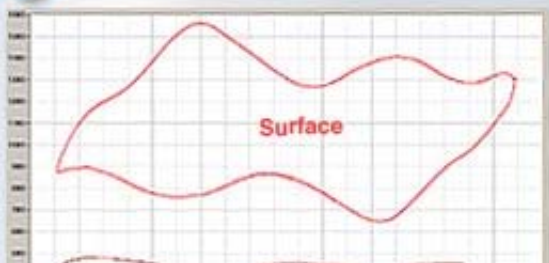
Figures 2 and 3 illustrate the results from a conventional pumping unit running clockwise rotation with a relatively constant crank speed. Figure 2 illustrates the polished rod and pump linear velocities. The rod speed peaks at 30 inches/sec (blue trace). The downhole pump speed peaks at 45 inches/sec (green trace). Figure 3 illustrates the corresponding surface and downhole dynamometer plots.

Conventional Pumping Unit

2 Pump and Rod Velocities

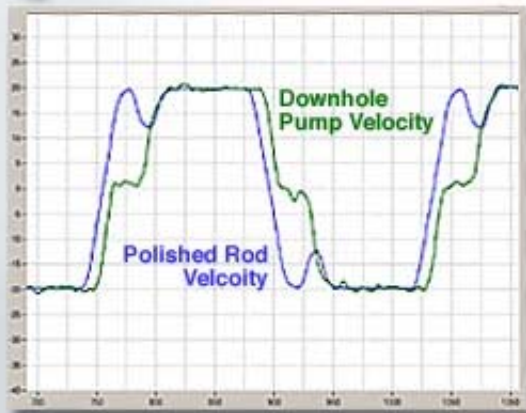


3 Dynamometer Plots



With Rod Damping Control

4 Pump and Rod Velocities



5 Dynamometer Plots





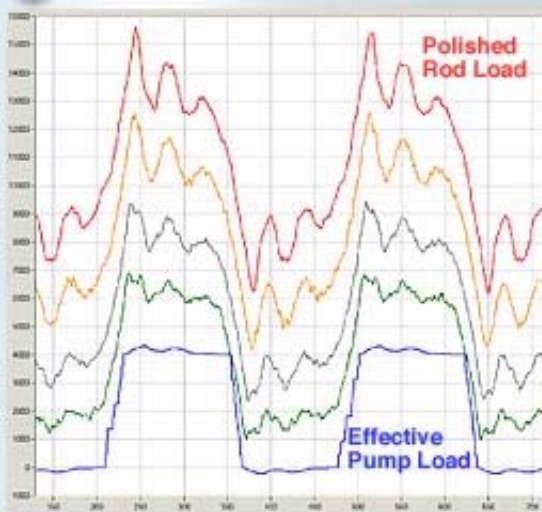
Figures 4 and 5 illustrate the results from the linear rod pump with surface motion profiling, specifically deadbeat rod damping control. The polished rod motion profile is manipulated very calculatingly so as to almost completely eliminate rod string dynamics. Peak velocities are limited. Whereas time was previously wasted by inauspiciously low acceleration rates during certain parts of the cycle, the velocity is now continuously manipulated in a more favorable way, improving overall response while maintaining the same average pumping speed. Figure 4 illustrates the polished rod and pump linear velocities, both peaking at 20 inches/sec. Figure 3 illustrates the corresponding surface and down-hole dynamometer plots. The rod damping control reduced the peak down-hole pump velocity to half its original value. Rod load dynamics (overshoot and oscillation) have been eliminated, reducing the peak rod differential loading by over 2,000 pounds.

To demonstrate the rod damping effect along the entire rod string, Figure 6 and 7 illustrate rod string loads from surface to pump (at various points down the length of the rod) without and with rod damping control. For simplification, buoyancy effects have been ignored. The rod damping case shows a considerable reduction in rod dynamics along the entire string, reducing rod fatigue and rod buckling potential. Generally speaking, the rod string is much better behaved. (To specifically evaluate rod buckling tendency, one would include buoyancy effects, which would shift the load lines down correspondingly; if the minimum rod load drops below a critical compressive value, the risk of rod buckling exists.)

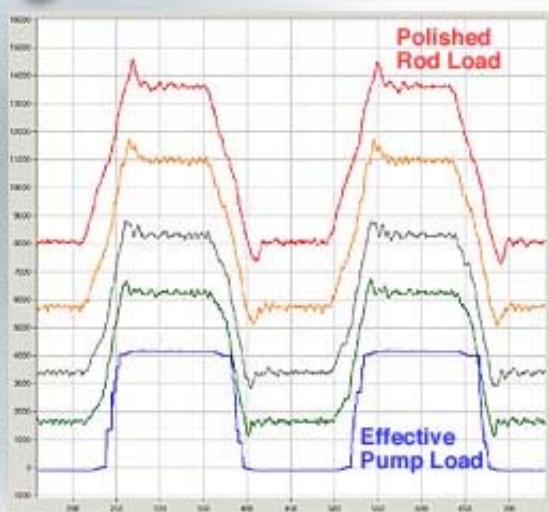
Conventional Pumping Unit

With Rod Damping Control

6 Rod String Load Distribution



7 Rod String Load Distribution



There are other advantages to surface motion profiling beyond controlling rod dynamics. For example, a “soft landing” feature can reduce the speed of the downhole pump just prior to fluid impact, reducing the impact force. In a similar fashion, peak upstroke pump speeds can be limited to reduce viscous flow pressure drop across the pump intake. Look for future articles on these topics and more.

For more information on surface motion profiling, please [contact us](#).

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Tools and Resources

Online Pump and Rod Selection Guide

A handy *Pump and*

Rod Selection Guide is now available online at www.unicous.com/en/pumprodselection.html. The guide is a convenient reference for determining the proper pump type and rod string percentages when designing sucker-rod pumping systems.

Percentage of Rod String Length by Diameter	3.000"	0.875"	0.750"	0.625"	0.500"	
					100.0%	
				44.6%	55.4%	
				40.5%	50.5%	
				56.4%	43.6%	
				64.6%	35.4%	
				72.7%	26.3%	
				83.4%	16.6%	
				93.5%	6.5%	
				100.0%		
				33.3%	33.1%	33.6%
				37.2%	35.9%	26.9%
				42.3%	40.4%	17.3%
				47.4%	45.2%	7.4%

The table provides the recommended proportions for tapered rod strings, based upon the American Petroleum Institute’s guidelines for designing rod-pumping systems (API Recommended Practice 11L, 1988). Given the rod number and plunger diameter, you can quickly determine the suggested percentage of the total string length for each rod diameter.

These percentages keep the stress on the top of each rod size approximately equal. The rod number is a two-digit designation where the first digit is the largest rod size and the second digit is the smallest, both in eighths of an inch. For example, a 65 rod is a two-way taper of 6/8" and 5/8" rods. An 86 is a three-way taper of 8/8", 7/8", and 6/8" rods.

The table also shows the recommended pump type for a given plunger diameter and tubing diameter. Pumps are indicated as RH for a rod insert pump with heavy walls, RW for a rod insert pump with thin walls, and TH for a tubing pump with heavy walls.

We hope this chart proves

useful. If you have comments or questions, please [contact us](#).

Product Watch

Solar-Powered Controller Increases Performance of Engine-Driven Sucker-Rod Pumps



Are you tired of using a divining rod to determine what's going on downhole? If you have an engine-driven jack pump, you know how tricky it can be to time the cycle of a well with varying inflow. Pump too long and you risk equipment damage; don't pump long enough and you sacrifice production.

Unico has a solution that not only takes the guesswork out of pumping, but one that works virtually anywhere since it operates using energy from the sun. The

system marries a sophisticated pump-off controller with a solar power system to form a self-sufficient tool for tapping the potential of wells located off the power grid. The system can be used with any engine-driven sucker rod pump.

The RPC Rod Pump Controller measures pump fill and intelligently regulates the pump-off cycle so that the well is never overpumped or underpumped. Should the pump fill ever drop below a specifiable setpoint, the unit shuts down the engine controller for a calculated pump-off time, after which the engine controller will automatically restart.

Prior to this technology, a producer had no idea what was happening downhole without expensive analysis equipment. There was no easy way to know how much fluid was being lifted or how much stress was being put on the pump jack or subsurface equipment. The RPC system eliminates the mystery with powerful diagnostic and reporting capabilities. When used with an inclinometer and load cell, the controller provides important well information 24/7, including pump fill, pump speed, minimum and maximum rod loads, pump loads, peak up and down torque, fluid over the pump, and barrels per day. An optional cellular modem and GMC™ package makes this data conveniently accessible from anywhere in the world at any time via the Web.



A solar-powered Rod Pump Controller at work on a 4,500-foot-deep gas stripper well located in the Great Lakes region of Pennsylvania in the Medina Play. The system performed well last winter, when frequent lake-effect storms meant heavy snows and little sunshine. The system can operate for seven days without the sun. This well was not producing for the customer. After installation, the RPC system clearly indicated that the problem was downhole. The traveling valves were not fully closing, causing the pump to leak. The problem was easily corrected. The economical RPC system provides both control and sophisticated diagnostics for about half the cost of traditional analysis equipment.

Unico's new SPS Solar Power System frees you from the electrical grid by using solar energy to power the Rod Pump Controller. The SPS unit is engineered with a 180 watt solar panel, a battery charger that incorporates MPPT technology to maximize power utilization, and a 258 ampere-hour deep-cycle glass mat battery for enhanced performance and service life. The SPS system is designed to operate the Rod Pump Controller for seven days without sunlight. The solar option eliminates utility costs and has a life of 20 to 25 years.

The RPC unit interfaces easily with digital meters, sensors, level switches, 4-20 mA analog signals, and with other devices using Modbus communications.

For more information about the Rod Pump Controller or solar-powered pumping, please [contact us](#).

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In Future Issues...

Look for the following articles in upcoming issues of *Oil & Gas Automation*

Solutions:

- Field tests of methods to eliminate rod pump gas locking and interference
- Reducing power consumption and improving power factor of beam pumps
- Using a torque economizer mode to improve efficiency and reduce gearbox stress
- Control options to ride through power disturbances
- Loss of methane gas production due to overpumping CBM wells
- Use of low-profile CRP® and LRP® pumping units with traveling irrigation systems
- Air counterbalance increases LRP® linear rod pump lift capacity

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