BEAM PUMP CONTROL TODAY

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ABSTRACT

A number of different methods of controlling beam pumping units are in use today and the important features of each are considered. Most of these controllers use the polish rod load (measured directly or by inference from the motor load) to determine the performance of the rods and pump downhole in the well. Whenever a variation in the rod load is seen indicating that the pump is not full of liquid, the controller shuts down the pump - usually for a fixed period of time. A new method which slows the pump motor by use of a variable frequency drive, allowing continuous operation, has been tested in West Texas. The advantages of this "pumpdown" method and preliminary results of the test program will be presented.

INTRODUCTION

Controlling the pumping rate to match the production of liquid from the reservoir has always been a problem for beam pump oilwells. But it is particularly difficult with the increasing use of fluid injection for enhanced oil recovery which causes frequent changes in reservoir production rates as injection rates change. Automatic beam pump control can be broken into two major aspects: (1) detecting when the pump speed is too high or low and (2) correcting the speed to eliminate the problem. Most of today's control methods use the polished rod or the electric motor load to solve the first problem. These loads change when there is reduced liquid in the subsurface pump indicating overpumping. The polished rod load is usually determined directly with a load cell on the polished rod or by a strain gauge which measures the deflection of the beam. The electric power can be measured directly or the speed of the motor can be used as an indicator of the load on the motor.

Most control systems in use today correct the speed by shutting down the pumping unit for a period of time so that the average speed matches the reservoir production rate. The extreme simplicity of the beam pump unit, which is one of its major advantages over other pumping systems, becomes a problem when it is necessary to continuously and automatically change the pumping rate to match the reservoir production rate. Frequent pump shutdowns of up to 100 times per day cause obvious maintenance problems with the electric motor and the sucker rods. If the pumping rate is too high, additional stress is caused by "fluid pound" which occurs when the descending pump plunger travels through the top portion of the pump barrel containing gassy liquid or gas and then meets the remaining relatively incompressible liquid creating a large compression force in the rod string. In many high volume wells with low reservoir pressures and low permeabilities, there will be a reduction in the production rate from the reservoir during the shutin period. The reduction occurs due to the backpressure on the reservoir from the fluid level which accumulates in the tubing/casing annulus of the well. However for many small volume producers where field people have the time to monitor the annulus fluid level closely and adjust the timeclock as needed, timeclock well control can be a simple, economical method for well control.

CONTROLLERS IN USE TODAY

Controllers used in significant numbers in the field today are generally split into two classes--those sensing the electric motor performance and those sensing the rod load. These controllers all use some method of on/off pumping time control to adjust the average pump capacity to match the reservoir performance automatically. An excellent survey of control methods was presented by Lea[1] in 1986.

Electric Load Sensing

Nabla produces a pump-off control system which measures the speed of the motor on every revolution using a magnet mounted on the rotating shaft which induces an electric pulse into a stationary transducer. A microcomputer is used to determine the motor speed for every revolution of the shaft. If motor manufacturer performance curves are available, the motor power, torque and load can be determined at each revolution of the motor. A reduction in motor power is used to signal pump-off and to shut down the pumping unit. Since there may be as many as 50 to 100 revolutions in a stroke, this data can also be used to generate a dynamometer card and torque curve for the beam unit. Gibbs[2] has shown that these plots compare favorably with actual polished rod load cell dynamometer cards. A similar system which uses changes in the average time for a pump stroke to detect pump-off has been developed by D-Jax. These systems depend on the motor belts not slipping and constant dynamic characteristics of the beam unit itself, but do not require load cells or beam position transducers.

Rod Load Sensors

For the maximum reservoir production rate, the ultimate objective of all of the methods of pump-off sensing is to determine the level of fluid in the well and to keep it at the perforation level. A number of different methods have been used to measure fluid level down the annulus but none has been used widely for pump-off control. Such a method described by Godbey[3] has a significant advantage over other methods as it can operate with the pump filled with liquid whereas most other methods require some gas in the pump for control purposes.

The most popular method of load sensing used today measures the polished rod load at the surface as an indicator of downhole pump filling. The closer the load sensor is to the downhole pump, the lower the compensation that must be included for changes in intervening equipment. Although some of the earliest work by Gilbert[4] involved downhole load determination, only recently has research returned to determining downhole load directly. This work by Purcupile[5] recorded the data downhole in a small computer which required removal to the surface for analysis and would not serve for continuous control. The industry seems to have settled on the measurement of the polished rod load using a load cell mounted between the carrier bar and polished rod clamp as the most accurate measurement of rod load. In most cases, use of the wave equation can give reasonably accurate pump loads from the surface data.

Since installation and maintenance of the load cell on the polished rod (which carries a heavy load) is fairly difficult in the field, EDI provides a strain gauge which is mounted on the top of the I beam and measures the deflection of the beam as the load varies. This load detector has been quite successful even though the beam metal temperature can change over a large range with problems for calibration and compensation.

Although not absolutely necessary for field control, most of the above mentioned systems include a method of determining the position of the polished rod during the stroke. Variable rheostats have been attached to the beam or to the carrier bar to provide an indication of stroke position. Other approximations to the rod motion have also been used.

Most of the rod load detection systems use the rod load at the beginning of the downstroke as an indicator of pump-off occurrence in the well. If the pump contains gas, the rods will not be supported by the liquid in the pump and will fall faster and exert a greater downward force on the polish rod. A normal dynamometer load card showing polished rod load on the upstroke and downstroke with the pump full of liquid is shown in figure 1. Whenever the pump becomes partially filled with gas indicating that gas is entering the pump, the dynamometer card is changed most on the beginning of the downstroke as shown in figure 2. The polished rod load is higher since there is no liquid to support the weight of the pump and rods above and to transmit the load to the standing valve and the tubing. This increase in load has been used by many pump-off controllers as an indicator of pump-off and the need to shut-down the pump until more liquid is entering the pump. It is possible to either use the load at a single point on the downstroke or to use the average load or power over some preselected portion of the downstroke as is shown in the shaded area in figure 2.

VARIABLE SPEED PUMPING

With increasing reliability and lower cost of solid state electronics, it is becoming feasible to use Variable Frequency Drives (VFD) to change the speed of beam pumping units. These VFD's are used throughout the industry to control water injection pumps and electric submersible pumps. The VFD systems consist of a very large rectifier which converts the alternating current at 60 Hz into direct current which is used to synthesize an alternating current of any frequency from nominally 5 to 80 Hz. Skinner[6] describes a method to use a VFD to control beam pumping speed using the electric power consumption of the motor as an indicator of a partially filled pump. Viatec uses a VFD to reduce upstroke speed and increase downstroke speed to reduce peak loads and permit higher beam pumping speeds in heavy oil production in California.

Teledyne Merla has developed a VFD pumping system shown schematically in figure 3 which relies on the dynamometer card power on a portion of the downstroke as an indicator of pump-off occurring. Since it is possible to operate continuously with the fluid level pumped down to the pump and the motor is never turned off, this has been called "pump-down" control instead of pump-off control. All actions of this system are directed by a rugged microprocessor-based controller. Speed and on/off control are provided to the VFD by a proportional band control algorithm. The controller also provides dynamometer card acquisition and calculations. Operating parameters and records are stored in the system and are displayed to the operator through simple menu displays on a laptop computer.

A major complication of the variable speed operation is the fact that the full pump dynamometer card has a widely varying shape ranging from rectangular at low speeds to sawtooth mountain shape at high speed when dynamic loads become significant. The bouncing of the rods can even have an effect on the downstroke so that the load is not constant at the beginning of the downstroke when the speed changes. In addition, viscous forces resist the downward falling of the rods through the oil in the tubing with a force that increases proportionally to the pumping speed and reduces the rod load at higher speeds. Teledyne Merla has overcome these complications in a manner that provides for reliable control over the pump speed range. The variations in calibrations at differing speeds is accommodated. Computer control allows this to be done automatically without operator assistance.

A prototype of the Teledyne Merla system mounted on a small trailer is being tested in West Texas by Texas Tech's Petroleum Engineering Department. Preliminary results have led to the following conclusions:

(1) Although increased production is probably occurring due to continuous operation with the fluid level at the pump, the low flow rate wells tested and field production test facilities do not permit accurate measurement. After field-wide shut-ins caused by storms and power outages, the automatic speedup and control provided as soon as power is restored results in increased production compared to hand-adjusted timeclocks.

(2) Since the fluid level is always at the pump, the increased net lift in the well results in increased power consumption. If the well is not counterbalanced properly and is functioning as a generator

during part of the stroke, the generated electric current cannot flow back through the VFD rectifier and is lost. The net result has been a 10 to 15% increase in power cost in the test to date.

(3) Continuous pumping keeps the wellbore warmer and probably reduces the need for paraffin removal (hot-oiling).

(4) This system can be used temporarily on wells after a workover or fracturing treatment to rapidly pump the returned fluid, allowing the well to be put back on production sooner.

(5) Since the VFD can be operated at one fixed speed in pump-off control, it can be used in well testing procedures which require various fixed production rates.

FUTURE CONTROL SYSTEMS

A great interest is developing in the use of the microprocessors that are being installed for control purposes as Artificial Intelligence or Expert Systems to diagnose operating well problems. At this time Baker has some limited diagnostics for rod overload and rod part in their pump-off controller. Svinos[7] has developed an off-line diagnostic program called EXPROD and Derek[8] has described an expert system for problem analysis that could be used on-line in problem solving. An expert system for on-line control is under development at Texas Tech for the Teledyne Merla controller described above.

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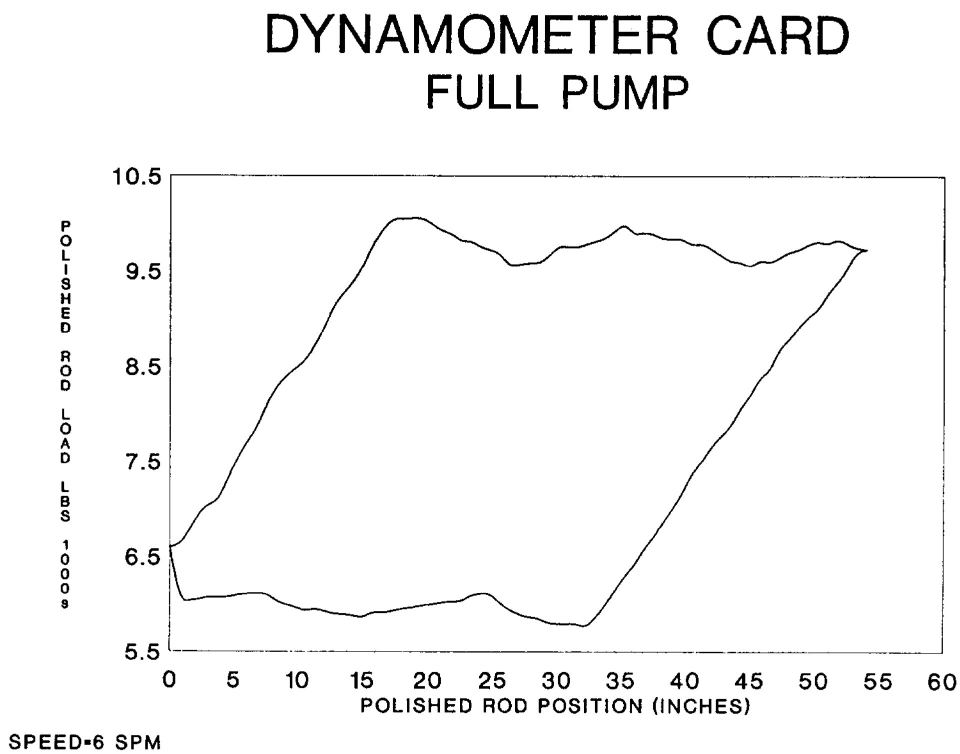

Figure 1 — Dynamometer load card
for a typical full pump

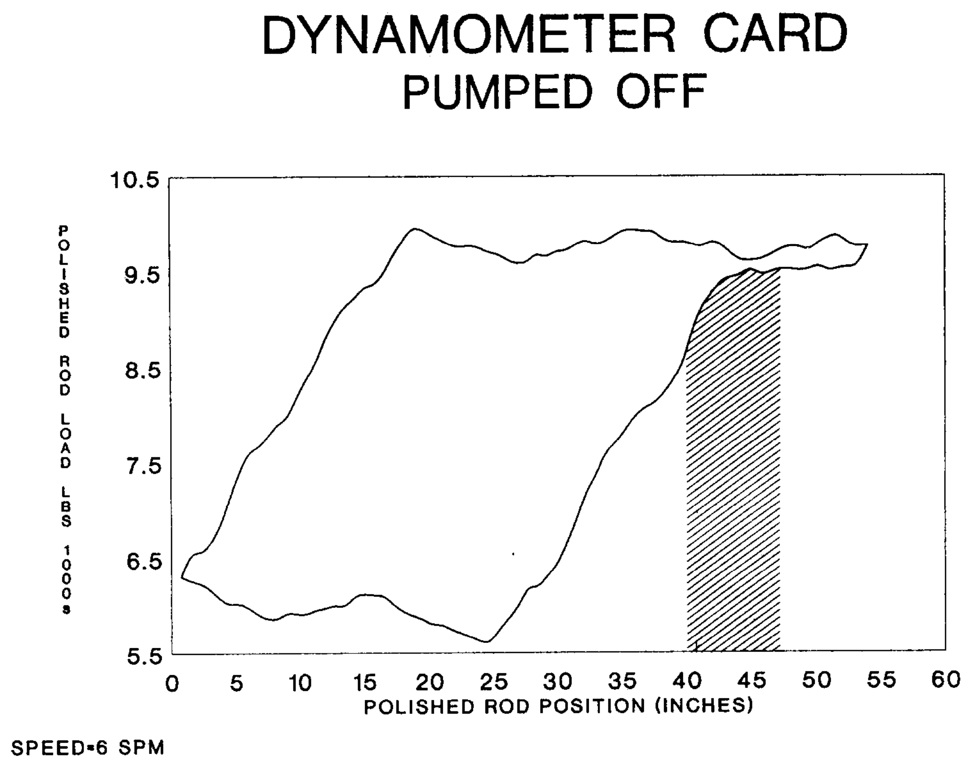

Figure 2 — Dynamometer load card for a partially filled pump illustrating fluid pound and the part of the downstroke used for pump-off control

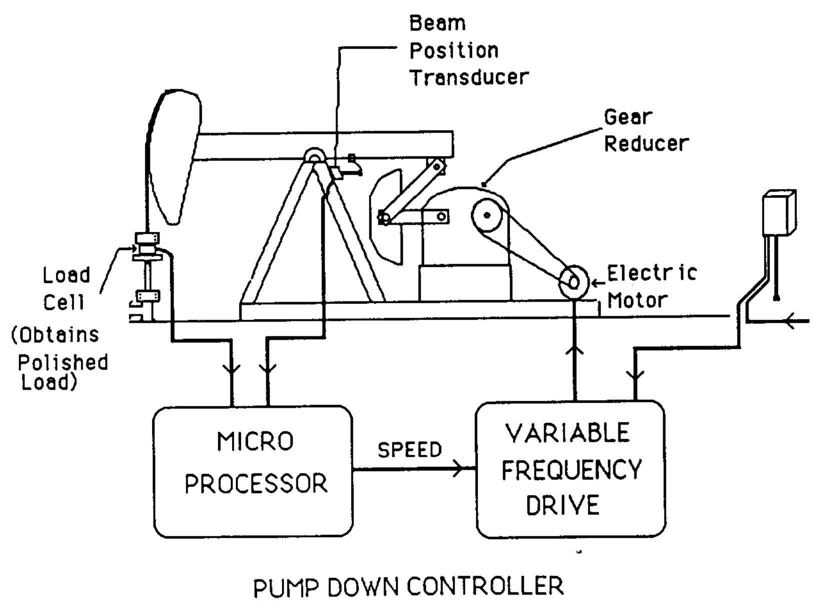

Figure 3 — Variable speed beam pump control by Teledyne Merla, Inc.