INNOVATIVE DEVELOPMENTS IN SUCKER ROD PUMPED WELL ANALYSIS

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Abstract: A systematic data collection is crucial for supervising a sucker rod pumped well’s operation. Not only should the surface technology be monitored from time to time but the well inflow parameters as well. This paper reports on new and promising research projects that deal with cheaper solutions of sucker rod pumped well analysis and are based on electrical measurement only. A comprehensive review of actual trends of analyzing the world’s beam pumped wells is also presented.

1. Introduction

Sucker rod pumping is the leading artificial lifting method in the world. More than 75% of the world’s artificial lifted wells are operated using beam pumping units [1]. This big number can be misleading because the majority of the sucker rod pumped wells are stripper wells, especially in the US. Such wells produce only 10 bpd or less. It can be assumed that the situation is similar worldwide and the most of the sucker rod pumped wells produce low daily rates. This recognition makes it important to find cost-effective solutions for supervising beam pumped wells. The dominating monitoring solution is the recording of dynamometer surveys [2] but other methods like smart well controllers, promising electrical measurement based solutions, etc. can also be found.

The conventional data acquisition system uses dynamometer surveys only that includes “well shooting”, and may include an electrical survey [2]. The operational parameters can be determined from the dynacard and some information is received about the motor’s operation if an electrical survey was performed. The counterbalancing of the unit can be checked using electrical measurements. The dynamic or static fluid level can be measured in the annulus so we get information on the well’s and reservoir’s condition.

Other types of data collection may be attained using smart well controllers equipped with remote monitoring or control facilities. This type of data acquisition gives a lot of informative data on the well and the reservoir. But smart well controllers are expensive and complicated and are not cost effective for stripper wells.

The new methods reviewed in this paper promise fast and cost effective measuring systems using only electrical measurements. That sounds well but the validating of those systems through statistically large sample numbers is the task of ongoing research.

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2. Smart well management systems

The objective of all smart rod pump control systems is the same: to achieve the highest production rate with the lowest production costs. The development of such systems began in the 70’s and 80’s with easy pump-off and timer controllers [3]. The early types of equipment were able to control the running time and later to detect the operation without fluid lifting. Then the availability of microcomputers allowed developers to include more functions in the rod pump controllers. Today’s smart well management systems are offered as a comprehensive system with remote monitoring facility, liquid flow measurement [4] using the pump as a flow meter, and are equipped with other important or practical parts. Figure 1. shows a modular rod pump controller that can be mounted on normal sucker rod pumping units.

Figure 1.: CAC 880 Rod Pump Controller [5]

The rod pump controller’s main control elements can be seen in Figure 1. : the LCD display, the touch panel, and the housing. Every important sucker rod pumping unit producer and service company offers their own smart well management or control systems.

The number of available smart well management systems is increasing every day, their have many common features which are collected in the following list [4, 5].

- online recording of dynamometer surveys
- overload-, fluid pound- and pump-off detection and automatic control of the operation
- timer facility
- HMI interface where every important parameter can be read out
- early failure detection
- data storage facility
- the controllers can be operated with Hall-sensors and other sensors
- optional: remote control facility
- optional: variable frequency drive for better optimization
The advantages just listed show that smart rod pump controllers can be adjusted for any given system. Producers stress the advantages only but there are some disadvantages as well. Normally each system should be adopted for the given unit which is not always easy. Such systems are relatively expensive when comparing them with a common dynamometer survey measurement. Manufacturers claim that investment costs are paid back through the enhanced production rates and lower workover costs. The use of smart rod pump controllers is probably advantageous for wells with quite high production rates. However, high investment costs are unreasonable for stripper wells or for wells which are close to abandonment. The solution for that category is a low cost monitoring or only periodical monitoring system that provides good information about the well’s condition. Those systems are the conventional dynamometer measurement packages or other promising, cost effective methods presented in the next paragraph.

3. **Electrical survey based solutions**

The industry practice uses conventional dynamometer surveys for analyzing sucker rod pumped wells [2]. The measurement is a routine task for the field operators but has some disadvantages:

- the well’s production should be stopped while the load sensor is installed because it is not possible to connect the sensor while the beam is operated
- needs qualified staff, which is always more expensive than the operator of a standalone low cost electrical measurement system
- the measurement should be repeated periodically
- the evaluation of dynamometer cards needs special skills
- the dynamometer and its data acquisition system are expensive.

Ongoing research projects are promising better solutions than dynamometer measurements: they only measure the electrical parameters. Than the most important operational data can be inferred using the asynchronous motor’s speed-torque characteristics. Gibbs-Miller [7] proved that steady-state motor performance data can be used in dynamic conditions when the motor performance curves were measured. The authors received reliable results when they calculated the torque on the motor’s shaft from the dynamometer card and they were able to predict the motor’s power consumption and line currents as well. The calculation’s direction was reversed by Silva et al. and Koncz [6,8]: who produced reliable surface dynamometer cards by measuring electrical parameters only. However, each method has a common requisite; motor performance curves should be known.

Some investigators [7] recommend measuring the performance curves. The measurement would be the safest and best way to get the steady-state performance curves but the measurement is complicated. Special dynamometers should be used and recording the data in the field is impractical. So this measurement is not easy and needs expensive laboratory equipment.

The other possible solution is the estimation of those performance characteristics. The determination of an electric motor’s performance curves is an interesting problem but it is still not really solved. The sucker rod pumping units are
equipped normally with NEMA D high slip motors. The high slip induction motor’s behavior differs from that of the normal, common NEMA B motors’. The main difference between NEMA B and NEMA D characteristics is that the high slip motor’s performance curve is not as steep as the normal NEMA B performance curve. This feature makes high slip motors suitable for use in sucker rod pumping, because the always changing cyclic load of the unit can be tolerated owing to the flexible characteristics and the current peaks and harmful mechanical effects can be minimized. Unfortunately NEMA D motors need special algorithms to determine their characteristics because of the special design [8].

Silva et al. [6] eliminate the problem and choose an easy way to the determination of the torque-speed curve. They assumed a linear torque curve between the nominal and the synchronous speeds. The other section of the characteristics is unknown. The motor’s actual speed is inferred using rotor slot analysis and then the torque produced at the motor’s shaft is calculated using the torque-speed characteristics. This method can give quite accurate results when the motor is oversized and the actual speed values are in the known range. However the method is not able to model properly sized motors working in regenerative braking and speeds below the nominal speed. Those conditions usually occur on well balanced and well sized pumping units. The following equation gives us the torques occurring in the surface system when the torque at the motor’s shaft is determined and the transmission ratio is known between the motor’s shaft and the gearbox’s slow-speed shaft:

\[ M_{net} = M_{pr} + M_{cb} + M_{rot} + M_{art} \]  \hspace{1cm} (1)

The pumping unit’s geometrical- and mechanical properties should be known to perform the calculation. Kis [9] presented the available calculation processes to determine each torque component. The polished rod torque can be determined in that way.

Koncz [8] deals with a more usable method for inferring performance curves. The torque-speed characteristics can be calculated on the whole speed range, from 0 to the synchronous speed and above when following the author’s recommendation. Although the calculated performance curves include some errors the method is still able to determine a good torque-time function at the motor’s shaft. This work can be continued in the future by including the torque calculation which depends on Eq. 1. The strengths of the two examined methods could be combined in one calculation procedure. Koncz [8] had a problem with the current-speed characteristics calculation but the torque calculation was perfect. Silva et al. [6] had a good speed determination procedure using the rotor slot analysis but the torque curves were not accurate enough. Combining both solutions may give an overall best method and the research can be continued in this direction.
4. Conclusion

An effective well supervising procedure is very important for the proper operation of sucker rod pumped wells. Optimum operation is achieved by using modern data acquisition systems and systematic data collection only. Available techniques were presented in this paper along with technical analysis about their applications. It was concluded that smart rod pump controllers are definitely good choices for high rate wells but they are not cost effective for stripper wells. Important ongoing researches were presented for stripper well measurement systems. The utility of electrical measurements was proved but the proper way of execution is still questionable. The importance of such research projects is high because they promise implementation of a complete well analysis with the use of cheap electrical survey.

5. List of symbols

- $M_{net}$: net torque on the gearbox
- $M_{pr}$: polished rod torque
- $M_{cb}$: counterbalance torque
- $M_{rot}$: rotary moment of inertia on the crankshaft
- $M_{art}$: articulating moment of inertia on the gearbox

6. References

[1] SPE online: http://petrowiki.org/Artificial_lift, 22.01.2015