Design of a Test Device for Oil Sucker Pump Efficiency

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Abstract. Aiming at the problem of experimental device for pump efficiency available, the new type of experiment device is designed in which the pump is driven by the horse head of the pumping unit directly. This device has an advantage of simulating the motion of pump with high precision. The experimental device includes the mechanical unit, signal monitoring unit and software system. Firstly, the mechanical unit is introduced, which the linkage department with pumping unit and the simulating department for oil well are designed. It can simulate the field condition better. Next, the data monitoring unit is discussed, which includes the pressure sensor, fluid rate sensor, transmitter and data sampling card. Finally, the software system of the experimental device is presented.

1. Introduction

The oil sucker pump is an important equipment in the oil production process and Its efficiency directly affects the production in the oil field [1]-[3]. But the prediction and modeling of pump efficiency exist the great difficulties and the large error. Therefore, it is an effective method for verifying the theoretical mode to establish a pump efficiency experimental device l [4][5].

At present, the most commonly used pump efficiency test rigs mostly use hydraulic cylinder and other active parts to drive the oil sucker pump [6]-[8], and they cannot simulate the motion of pump plunger, the mixing flow of downhole gas-liquid, the fluid pressure in the pump entrance and other complicated work conditions.so they have some shortcomings. For this reason, a new pump efficiency test rig is developed to simulate the movement law of the oil pump in the underground which is driven by the horse head of the pumping unit directly. By simulating the parameters, such as the mixture fluid pressure of gas-liquid in the oil sucker pump inlet and outlet, the working conditions of the oil pump becomes more real. As a result, the pump efficiency measured by the test rig is more consistent with the actual oil well site.

2. Structure and working principle of the experimental device

2.1. Calculation model of oil sucker pump efficiency

There are many calculation methods of pump efficiency, which are mainly divided into two categories. The first is based on the multiplication of rod stroke loss coefficient, pump leakage coefficient and liquid volume shrinkage coefficient. The second one is calculated according to the actual volume of liquid produced by the oil sucker pump. The first is used for pump efficiency prediction, but the second for pump efficiency calculation. For the test rig of the oil pump, the second models are mainly used. The formula is as follows:

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$$\eta = \frac{q_S}{q_L} \tag{1}$$

In Eq.(1), η is the efficiency of oil sucker pump; q_S is the actual pumping liquid volume within a certain period of time, and Its common unit is m3/d; q_L is the theoretical pumping liquid volume within a certain period of time, and Its common unit is m3/d. The equation for calculating q_L can be written as:

$$q_L = 10^{-6} \times 1440 \times \frac{\pi D_p^2}{4} Sn \tag{2}$$

In Eq.(2), D_p is the nominal diameter for oil sucker pump and Its unit is mm; S is the plunger stroke of the oil sucker pump and Its unit is m; n is the plunger frequency of the oil sucker pump and Its unit is min^{-1}.

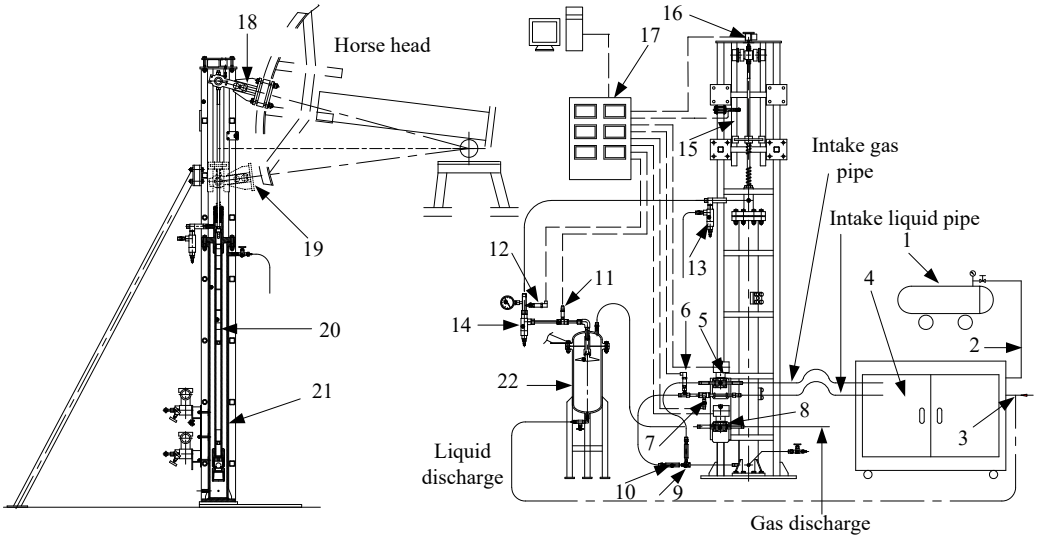
2.2. Overall structure of the test rig

The test rig is mainly composed of the liquid and gas supply device, the wellbore simulation device, the liquid discharging device, the pumping unit motion connection device, the computer monitoring device and so on. The liquid supply and gas supply device consists of air compressor 1, intake gas pipe 2, inlet fluid pipe 3, liquid and gas supply device 4, gas-liquid mixer 9, inlet one-way valve 10 and other components, and Its function is to provide gas-liquid mixture of a certain pressure for the inlet of the oil sucker pump to simulate the working conditions of oil well. The wellbore simulation device is composed of oil sucker pump 20, casing pipe 21 and internal connection parts and Its main function is to simulate the connection between the casing pipe and the oil sucker pump, and to serve for the production of liquid. The pump is the type of 38mm pipe-type oil sucker pump on the oil well site. The liquid discharging device mainly comprises the overflow valve 13, the outset throttle valve 14, the gas-liquid separation tank 22 and other components, and It has the main function of simulating the working conditions at the oil sucker pump exit , providing certain pressure in the pump outlet, and separating them from the gas-liquid mixed fluid the oil sucker pump discharge, which is convenient for the measurement of the actual discharging liquid volume. The main parts of the computer monitoring device are related sensor and transmitter unit 17, including entrance gas flow meter 5, inlet pressure gauge 6, entrance liquid flow meter 7 which is used to the working conditions at the oil sucker pump entrance, outlet gas and liquid flow meter 11, outlet pressure gauge 12 used to the working conditions at the oil sucker pump exit, counter 15, displacement sensor 16 which is used to monitor the stroke of oil sucker pump so as to calculate the theoretical displacement, as depicted in formula (2).The function of the pumping unit motion connecting device 18 is to connect the horse head and plunge to directly drive oil sucker pump plunger doing vertical reciprocating motion, and to realize the function of pumping liquid .

2.3. Working principle of Test-bed

In Figure 1, the gas and liquid supply device 4 exports liquid and gas with the required pressure according to the setting pressure and flows through the inlet liquid pipeline 3 and inlet gas pipe 2, then mixes at the gas-liquid mixer 9. Finally, the gas-liquid two-phase mixture flows into the casing space below the oil sucker pump to simulate the working conditions of the bottom of oil well. When the horse head starts doing reciprocating swing movement after starting the pump unit, sucker rod will be drove to do up and down reciprocating motion through the motion connection device 18. Then It drives the pump plunger doing similar motion, and finally realize the pumping action. The gas-liquid

two-phase mixture discharged by oil sucker pump flows into the outset throttle valve 14 through pipe. Adjusting the size of the throttle valve opening can change the pressure of the pump outlet, so as to simulate the back pressure of the outlet of the downhole oil sucker pump. The fluid flowed through the throttle valve 14 move into the gas-liquid separation tank 22, then the gas is discharged through the pipeline above it and the liquid through the lower pipeline. In order to recycle the liquid which is called water, it can be discharged back to the water tank in the of the liquid and gas supply device 4.
In the process of reciprocating swabbing liquid, the exit liquid flow meter 11 can detect the liquid volume discharged by the oil sucker pump. The counter 15 and the displacement sensor 16 can measure the stroke. The actual efficiency of the oil sucker pump can be calculated by taking these data into (1) - (2).



1 - Air compressor; 2 - Inlet gas pipe; 3 - Inlet liquid pipe; 4 - Gas and fluid supply device; 5 - Inlet gas flowmeter; 6 - Entrance pressure gauge; 7 - Entrance liquid flow meter; 8 - Outlet gas flow meter; 9 - Gas-liquid mixer; 10 - Entrance one - way valve; 11 - Exit liquid flow meter; 12 - Outlet pressure gauge; 13 - Safe overflow valve; 14 - Outset throttle valve; 15 - Counter; 16 - Displacement sensor; 17 - Transmitter unit; 18 - Motion connection device; 19 - Dead point position under the motion connection device; 20 - Oil sucker pump; 21 - Casing pipe; 22 -Gas-liquid separation tank

Figure 1. Overall structure of the pump efficiency test rig of oil sucker pump

3. The computer monitoring system

The structure of the computer test system mainly includes 7 sensors and a counter which is shown in Figure 2. These sensors convert their detected signals into electrical signals, and output 0~+5V standard current signals to the computer data acquisition card through a transmitter. The liquid pressure sensor, liquid flow sensor and gas flow sensor in the oil sucker pump inlet are mainly used to reflect the working conditions of the oil pump inlet. When the detected is different from the setting, it can be adjusted by the adjusting valve on the gas and fluid supply device. However, the pressure sensor, liquid flow sensor and gas flow sensor in the oil sucker pump exit are mainly used to reflect the working conditions of the oil pump outset. When the detected is different from the setting, it also can be adjusted by the throttle valve.

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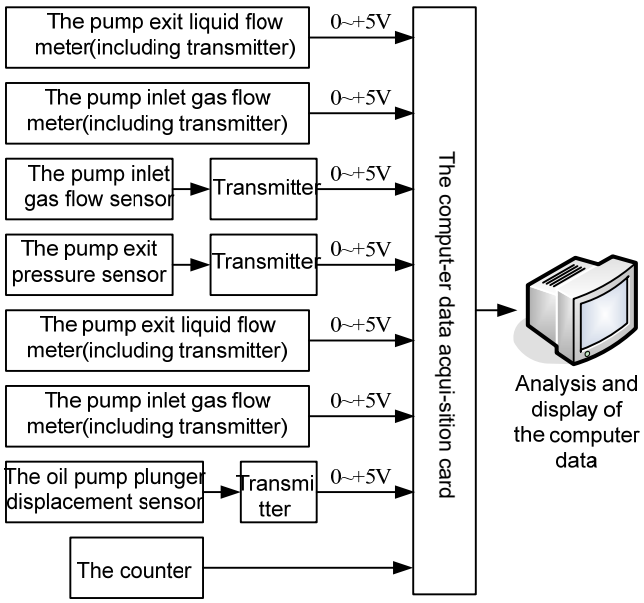


Figure 2. Signal detection device

4. Software System

This software is developed by vb6.0, and it is composed of data collection, pump efficiency calculation, result display, data storage and assistance, and so on, which is shown in Figure 3. The data collection is mainly through the calling the AD function of the PCI8336A board to read all kinds of analog voltage signals or switching signals into the computer. On the basis of the data such as the stroke, the stroke, the volume of the actual discharge of the liquid, etc, the pump efficiency calculation is figured out according to the formula (1). The results display is putting the calculated pump efficiency and various data on the main software interface, respectively, in the form of digital and curve. Data storage is storing the data in the TXT file for the sake of further analysis.

The software flow pattern is shown in Figure 4. The first step is to initialize the PCI8336A data collection card and call the own function of the card. And then, the timer control should be used in VB6.0 and the time interval is set to 500ms. At the beginning of the cycle, the data of each port should be collected, and all the collected data are stored in different TXT files. After that, we begin to calculate the theoretical displacement of pump, and then work out the pump efficiency. After calculating the pump efficiency, the actual pump efficiency and related parameters are displayed on the main software interface for the operator to check. After finishing a cycle of the data collection, the software will ask whether to carry on the next collection or not. If the user presses the stop button on the main software interface, the data collection is finished and the program is quit, otherwise the next data collection and pump efficiency calculation will be carried out.

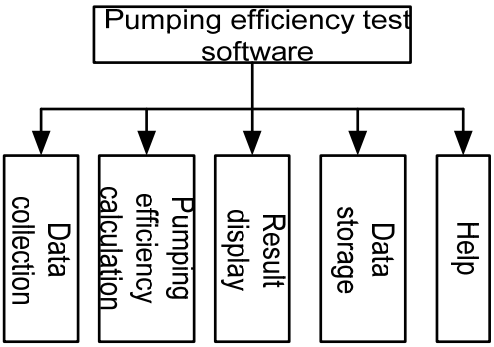


Figure 3. Software structure

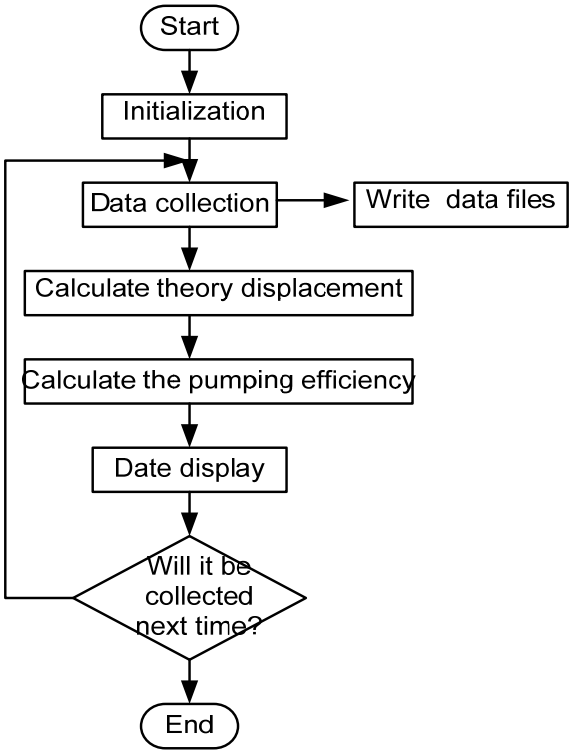


Figure 4. Flow chart of the pump efficiency analysis software

5. Conclusion

The test of oil sucker pump efficiency is a verification of the prediction model of the pump efficiency, which is of great significance for the oil recovery process. This paper studies the experimental device of pump efficiency whose direct drive is from the pumping unit by increasing the motor connecting device and connecting the pumping unit horse head and pump plunger. So, it can simulate the motion of sucker oil pump more realistic. The key to design and debug the mechanical device of the pump efficiency test is the motion adapting device and wellbore simulation device as well as discussion of the working principle and the problems encountered. Finally, the data detection device of the test platform and the software system are analyzed. This test platform has been running in our laboratory for more than two years with a good result in application.

Acknowledgments

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