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Experimental Study on Improving Production Efficiency of Gas Well by Plunger Lift#

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ABSTRACT

Currently, China's oil and gas resources are in a state of long-term shortage, and the technology for oil and gas exploration and development still lags behind that of developed countries. There is a need to intensify research on key technologies to enhance the development efficiency of oil and gas fields, especially those with remaining oil and gas resources. Plunger gas lift technology offers high economic efficiency in the mid-to-late stages of oil and gas reservoir development, but there is still considerable room for improvement in its application. Currently, the primary factors affecting the efficiency of this technology and their interrelationships remain unclear. To investigate the impact of various factors on the efficiency of plunger lift under identical conditions, and based on real physical conditions, not assumptions, a suit of indoor experiment equipment is designed that can measure weight changes of water which lifted from tubing every plunger lift period. According to the experimental data, it can be found that: Through this technology, the efficiency of water drainage and gas production in a single well can be increased from 82% to 90%; The efficiency of plunger lifting is nonlinearly related to the wellbore inclination angle, and there is a minimum efficiency point around 10 °; The average lifting efficiency of the plunger is highest when the diameter is 60mm; PRG has higher efficiency at smaller inclination angles (0 °~20 °).

Keywords: Plunger lift, Lifting efficiency, indoor experiment

NONMENCLATURE

Abbreviations	
PRG	Plunger with Ring Groove
PG	Plunger without Groove
ID	Inner Diameter
GST	Gas Storage Tank
PRV	Pressure Reducing Valve
GLST	Gas-Liquid Separation Tank

1. INTRODUCTION

China has been short of oil and gas resources for a long time. Since China became a net oil importer in 1993, the import volume of oil and gas has increased year by year. According to the prediction of the Chinese Academy of Engineering, the International Energy Agency (IEA) and other units, China will be in a long-term shortage of oil and gas in the future. The dependence on foreign oil will increase from 65% in 2015 to more than 80% in 2030. A significant increase in the ratio of oil and gas resources is of practical significance for reducing pollution and improving people's living standards. China's oil and gas exploration and development technology still lags far behind developed countries. The proportion of leading high-tech technologies does not exceed 30%, and more than 60% of technologies are in the tracking state. The research and development investment in key technologies for oil and gas exploration and development in China is small and highly variable, which is not conducive to the generation and application of original technologies. It is necessary to adjust the investment ratio of basic research, technology research and development, and large-scale application. At present, high-water-cut oil and gas wells have abundant remaining resources and still have high development value. The methods for discharging bottom hole fluid mainly include pump lifting, velocity string, bubble discharge, and plunger gas lift. Due to its high economic efficiency, plunger lift is an important gas drainage production process in gas well [1]. This technology can effectively develop remaining oil and gas resources and help reduce greenhouse gas emissions.

The principle of plunger lift is: by inserting a plunger which can move up and down into the wellbore to create a physical barrier between the gas phase and the liquid phase, relying on the energy of the formation itself, the accumulated fluid at the bottom of the well is promptly discharged, to ensure continuous production of the gas

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well. However, the efficiency of plunger lift is influenced by various factors, for example, the plunger will be worn after long-term use, and the decrease in plunger diameter will increase the size of the gap between the plunger and the wellbore, which has a direct impact on the lifting efficiency; In directional and horizontal wells, changes in the wellbore angle can alter the position of the plunger within the wellbore, which may cause more fluid loss; and different structures have different performances, choosing an appropriate structure can lead to a higher efficiency.

Since the 1980s, many theoretical and experimental studies on the plunger gas lift process have been carried out, various hypotheses have been proposed based on different focuses[2]~[8]. But when considering the influence of multiple factors at the same time, there are many contradictions between the models, and most of these results are not comparable. Therefore, it's necessary to conduct experimental study with multiple factors under the same conditions.

2. MATERIAL AND METHODS

2.1 Experimental equipments

There are various types of plungers, but they are all modifications of the rod-shaped plunger, and the surface of plunger will be provided with various grooves to increase the sealing performance as usual. Therefore, two kinds of rod-shaped plunger, with ring groove (PRG) and without groove (PG), are used in the experiment.

In existing theoretical and experimental studies, there are many sizes of experimental columns involved, and various plunger diameters are selected. In actual production, the plunger gas lift process is often applied to oil pipes with inner diameters of 50.8mm, 62mm, and 76mm. In order to unify experimental conditions, a 62mm inner diameter organic glass tube was selected as the visualization experimental section in this study. Because the diameter of the plunger will change with wear and tear during operation, this article chooses a plunger diameter of 58-61mm to explore the impact of changes in plunger diameter on plunger motion.

The maximum inclination angle of directional wells is usually within 55 °, and the inclination angle of the plunger seat in high inclination and horizontal wells is usually within this range. Therefore, this experiment chooses to explore the influence of 0 ° -50 ° inclination angle on plunger movement.

In order to strictly control the experimental condition variables, the pressure of the gas storage tank was fixed at 0.2 MPa to simulate the formation pressure, the downstream pressure of the gas storage tank outlet pressure reducing valve was fixed at 0.15 MPa to simulate the bottomhole flow pressure, and the injection volume in the wellbore was fixed at 4.8 kg (2m liquid column) to simulate the bottom liquid accumulation. Before opening the well, the wellbore pressure needs to stabilize, and the timing of opening and closing the well is determined by the upper computer. The actuator completes the action to control the instantaneous flow rate, pressure gradient changes, and other factors after opening the well to remain the same. Due to the fact that changing the shape of the plunger in actual use will inevitably cause a change in the mass of the plunger, this experiment uses the addition of counterweights to achieve the same mass for plungers with the same basic shape.

The main experimental parameters are shown in Table 1.

Tab1. The main experimental parameters

item	parameters
Diameter of plunger	58~61mm(gap1mm)
Weight of plunger	1.6kg (PRG)\2kg (PG)
Length of plunger	400mm
ID of tubing	62mm
Length of tubing	6000mm
Inclination angle	0°~50°(gap10°)
Gas tank pressure	0.2MPa
Tubing pressure	0.15MPa
Weight of liquid	4.8kg(2m)

The plunger gas lift experimental device designed in this article simulates downhole fluids using water and air provided by a pump and an air compressor; The measurement and control system is used to implement switch well control in experiments. The host computer communicates and controls various sensors and actuators through a data acquisition card, the device is shown in Figure 1.

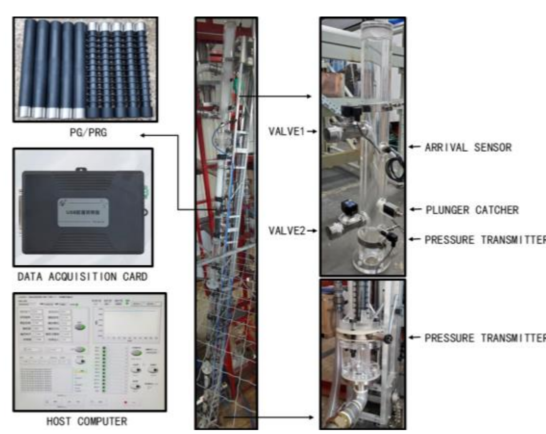

Fig. 1 The plunger gas lift experimental device

2.2 Experimental process

The experimental process is as follows: compressed air from the gas tank passes through the pressure reducing valve and join up with liquid that from the water pump at the check valve before entering the tubing. Opening vale 1, the gas and liquid above the plunger enter the gas-liquid separation tank through the valve 1. After the plunger is captured, the valve 1 and valve 2 are switched to allow the gas and liquid below the plunger to return to the water tank through the valve 2. At the end, weighing the liquid in the gas-liquid separation tank and return it back to the water tank. The experimental process is shown in Figure 2.

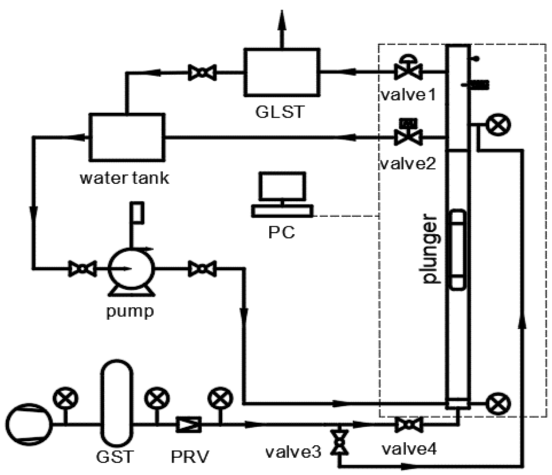

Fig. 2 The experimental process

2.3 Experimental method

Before the experiment, check whether valve 3 and valve 4 are closed. Restore the pressure of the GST to 0.2 MPa, adjust the PRV to make the downstream pressure be 0.15 MPa, install the plunger into the tubing, and check whether valve 1 is closed and valve 2 is opened. At the beginning of the experiment, close valve 2 and inject the liquid into the tubing with the pump. Stop injecting when the liquid column reaches a height of 2 meters. Open valve 3, and after the pressure increase rate in the tubing decreases, open valve 4 to quickly balance the pressure in the tubing and prevent leakage of the liquid. While the pressure in the tubing tends to be balanced, open valve 1, the plunger will move up to the top of the tubing and be captured. At this time, switch the valve 1 and valve 2. Weighing the liquid in the gas-liquid separation tank and return it back to the water tank. Close valves 3 and 4, and release the plunger.

3. RESULTS AND DISCUSSION

There is a complex relationship between the factors that affect the efficiency of plunger lifting. For example, increasing the diameter of the plunger can reduce the gap area between the plunger and the wellbore, thereby reducing liquid leakage. At the same time, it will increase the friction between the plunger and the wellbore, resulting in a slower change in plunger speed, which will further reduce the amount of leakage per unit time. However, this will also increase the total time it takes for the plunger to rise, and in total time, the amount of leakage will actually increase. Therefore, it is necessary to discuss the contribution of various factors to lifting efficiency and how these factors affect it.

3.1 The effect of well inclination angle

As the well inclination angle changes, the efficiency of plunger lifting is nonlinearly related to the well inclination angle, and the lifting efficiency of each plunger has a similar trend. As the angle increases, the efficiency decreases first and then increases. The lowest efficiency point appears at 10°. The lifting efficiency of different angles is shown in Figure 3.

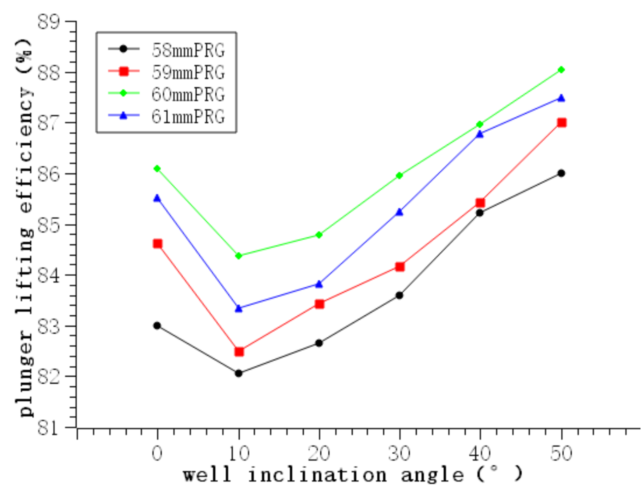

Fig. 3 The lifting efficiency of different angles

From the above results, it can be seen that for gas wells that may use plunger gas lift technology in the later stage of production, it is advisable to minimize the inclined section of about 10 ° when designing the wellbore trajectory during the drilling stage. This can greatly improve production efficiency when applying plunger gas lift technology.

3.2 The effect of plunger diameter

As the plunger diameter changes, the lifting efficiency of each plunger has a similar trend. As the angle increases, the efficiency increases first and then decreases. The highest efficiency point appears at 60mm. The lifting efficiency of different plunger diameter is shown in Figure 4.

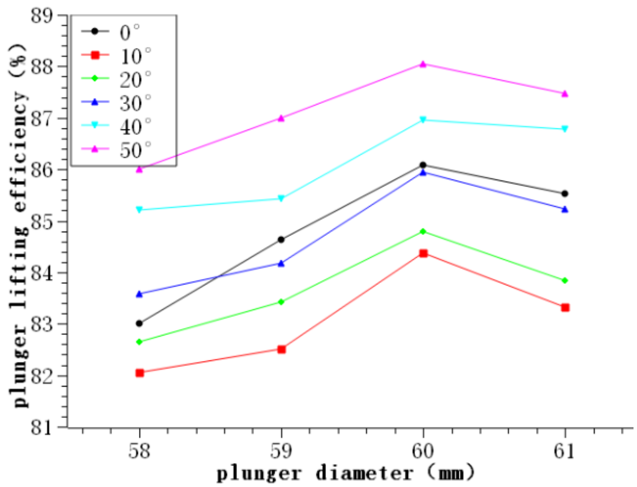

Fig. 4 The lifting efficiency of different diameter

From the above results, it can be seen that for a tubing with an inner diameter of 62mm, the optimal plunger diameter is around 60mm. The sealing effect of the plunger in the tubing is not necessarily better with a larger diameter.

3.3 The effect of plunger structure

When changing the plunger's structure, the lifting efficiency of each plunger has a similar trend. But within the range of 0° to 20°, the lifting efficiency of PRG is higher than that of PG, and within the range of 30° to 50°, the result is opposite. The lifting efficiency of different plunger structures is shown in Figure 5.

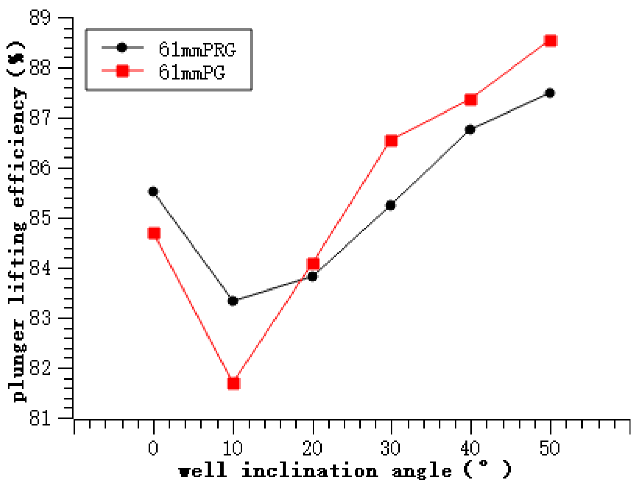

Fig. 5 The lifting efficiency of different structures

From the above results, it can be seen that different plunger structures have optimal advantages at different wellbore angles. The plunger structure should be selected according to the wellbore structure to effectively improve lifting efficiency.

Based on the above results, the wellbore inclination angle plays a decisive role in lifting efficiency, and there exists an optimal plunger diameter and structure for specific wellbore diameters and structures.

4. CONCLUSIONS

(1) Through this technology, the efficiency of water drainage and gas production in a single well can be increased from 82% to 90%.

(2) The efficiency of plunger lifting is nonlinearly related to the wellbore inclination angle, and there is a minimum efficiency point around 10 °.

(3) The average lifting efficiency of the plunger is highest when the diameter is 60mm.

(4) PRG has higher efficiency at smaller inclination angles (0 °~20 °). Therefore, for specific wellbore structures, there exists an optimal combination of plunger structure and size.

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