Design of Bidirectional Wireless Transmission System Based on Wellbore Pressure Pulse Signal

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Abstract. To solve the problem that the downhole data cannot be transmitted in real time and the downhole condition cannot be known in time during the well injection process, the downhole data wireless transmission technology was designed and developed. The wireless transmission method of downhole data signal was studied and the data encoding method was invented. The control circuit of intelligent measuring and adjusting instrument was designed for layered water injection. In 2019, the field test was carried out, which verified the feasibility of downhole data transmission method. The preliminary success of the wireless downhole data transmission technology can promote the development of intelligent well injection technology.

1. Introduction

In order to effectively solve the problem of water driving imbalance caused by the contradiction between different layers, to employ each oil layer as possible and improve the production of poor oil layer, separate layer water injection has become one of the important measures to supplement formation energy in recent years.

For the conventional separate layer water injection technology, such as eccentric or concentric water injection technology, steel wire or cable must be lowered to realize measuring-adjusting and the construction workload and operation risk are relatively large. The test data is too small and the operation monitor cannot last for a long time. In addition, due to the influence of pressure fluctuation, formation water absorption capacity other factors, it can only grasp the instantaneous separate water injection performance and the qualified rate of separate injection drop quickly due to the injection allocation cannot be adjusted in time.

In the paper, the intelligent separate layer water injection system based on bidirectional wireless transmission was developed. The functions of automatic measurement and adjustment of stratified flow, automatic pressure drop test, automatic seal inspection of packer and real-time monitoring and recording of stratified water injection parameters in the well were realized. In recent research, there were few researches on the wireless intelligent separate water injection technology which can realize the bidirectional real-time communication. Some research focused on the research of device and process principle, and the key measurement and control technology intelligent separate water injection had not be mentioned. Considering the geological characteristics of oil and gas fields in China, the wireless data transmission technology based on fluid wave code for intelligent separate water injection was developed, which can meet the requirements of low-cost development of oil and gas fields in China. It could also be applied in complex well conditions, such as highly deviated well, horizontal well, multi-branch well
and so on. The field tests showed that the subdivision degree of water injection wells, testing and adjusting efficiency, water injection qualification rate and other indicators have been greatly improved by using the technology.

2. Principle of downhole intelligent injection
After the completion of the intelligent separate layer water injection string setting, the water injection volume of the intelligent water distributor of each layer is adjusted under the mode of stable pressure by the electric control regulating valve in the surface water distribution room.

![Figure 1. Intelligent injection ground control and test system](image1)

![Figure 2. Downhole controllable water distributor](image2)

The pressure wave code is formed by opening and closing the electric control valve on the wellhead (pressure reduction method). The instruction information is transmitted to the downhole water distributor of the well. As shown in Fig.1 and Fig.2, based on the configuration of intelligent injection ground control and test system, when it is necessary to transmit the command data, the signal is first sent through the comprehensive signal control cabinet at the wellhead. When the downhole intelligent testing instrument at the water distributor received the data in the form of pressure wave, the underground motors would be driven through high-energy downhole batteries. When the motor quickly opens the mechanical valve or solenoid valve to establish the production fluid bypass, a momentary pressure drop $\Delta P$ will be formed at the wellhead, and a pressure drop related to the depth and slightly less than $\Delta P$ will be formed at the location of the downhole intelligent water distributor.

Based on the above principles, the motor was controlled by the intelligent testing instrument, and the opening of the downhole production access was adjusted according to the ground command. When the opening of the downhole adjustable production access changed, the flow and the internal and external pressure of the production access would change, and the change of the internal pressure would directly cause the fluctuation of the wellhead pressure. When the pressure transmitter on the wellhead which
was integrated in the control cabinet captured the fluctuation of the pressure, the downhole production
data was transmitted to the wellhead successfully. If the downhole data was continuous transferred in a
certain format, it could be decoded into a group of effective data after being captured by the wellhead
to complete the upload of downhole data. The technology is less affected by formation resistivity,
completion method and wellbore fluid, and can realize wireless data transmission in deep wells.

3. Data transmission technology

3.1. Data encoding mode
When the control command was transmitted to the downhole water distributor, the control system was
in a dormant state under normal working conditions to save power. The ground wellhead integrated
control cabinet provided external trigger signal, and the pressure sensor of the downhole controller
detected the pressure pulse signal, then activated the control system to make it be in active state. When
an effective pressure pulse was detected, the signal was amplified, the validity of the data was verified,
and the specified working movements were actuated based on the ground command.

When the underground production data was transmitted to the ground, the underground controller
would take the stored pressure, temperature, state and flow data, carry out binary coding, package the
data frame according to the specific data format, actuate the motor, adjust the opening of the downhole
production access, and output the data signal according to the position. The change of the pressure in
front of the production access would cause the change of the wellbore pressure. The surface wellhead
pressure gauge captured the the pressure fluctuation as the signal input, and the wellhead integrated
signal control cabinet analyzed and stored the downhole production data.

The control command transmitted from the ground to the underground took the form of n+m to
generate the signal. N was the corresponding layer, and m was the corresponding action command. The
downhole parameter data signal uploaded was a set of pressure pulse, and the main transmission contents
consisted of pressure, temperature, and state and flow data. The data coding format was synchronization
code + 16 bit data bit + check code, as shown in Figure 3.

![Figure 3. Data coding structure diagram](image)

3.2. Control system design
Downhole control system was the core of the whole bidirectional wireless transmission system, which
included underground controller, brushless direct current motor (BLDCM), downhole motor drive board
and battery pack. The hardware circuit of the downhole control board mainly included a power
conversion part (3.93V-3.3V), a main control module, a silicon oscillator, an EEPROM, a temperature
sensor, three pressure sensors, three amplification circuits, one comparator decoding circuit and one USB interface. The downhole motor drive board was mainly used to drive the DC brushless motor, which was directly powered by three 6.2ah/3.93v batteries in series. The downhole control board and the motor drive board shared the same ground. The control board provided control signals to the motor drive board. The DC motor was controlled by the integrated drive circuit. In addition, the over-current protection design was added. The three-way pressure acquisition circuit was adopted. The first way was to collect formation pressure. The second way was to collect the downward pressure in the wellbore, which had two functions: one was to provide the data of pressure difference for the calculation of downhole flow, and the other was to realize the pressure pulse signal decoding function. The third way was also to collect the downward pressure in the wellbore, which has two functions: one was to wake up the sleep state, the other was to decode the pulse signal hardware.

4. Field test
In July 2019, the field test of intelligent water injection system based on bidirectional wireless data transmission was carried out in Huang 16-5 well located at Jianghan Oilfield. Well Huang 16-5 was used as a test well for principle test of downhole wireless data transmission technology. The wellhead pressure test curve was shown in Fig.4.

(1) Tools preparation: one set of intelligent water distributor (including intelligent measuring and adjusting instrument), two pressure gauges (one was installed in the water incoming room and one was installed at the wellhead), one integrated signal control cabinet at the wellhead (including the wellhead pressure pulse generator).

(2) Test program setting: the setting of the program gave priority to simulate the possible action parameters of all well conditions through the test. The electric energy, the storage capacity of pressure gauge and the convenience of construction need to be taken in account.

![Figure 4. Wellhead pressure test curve](image)

The recording data of sensors in the field test was shown in Tab.1. And the following conclusions could be obtained through the data analysis:

a. The curve wave form was in good agreement with the field construction process and test procedure;

b. When the downhole water injection access worked normally, the maximum pressure difference reaches nearly 8Mpa, which was enough to be captured by the wellhead sensor system.
### Table 1. Recording data of sensors in the field test

| Locations            | Indoor (HZ)       | Starting time | Ending time | Original data | Effective data |
|----------------------|-------------------|---------------|-------------|---------------|----------------|
| Wellhead             | T:16020;P:6000    | 6:57          | 20:05       | 87218         | 87816          |
| Water-incoming       | T:16644;P:5800    | 7:04          | 20:10       | 86414         | 85796          |

5. Conclusion

In this paper, the wireless bidirectional data transmission system of intelligent water injection system based on wellbore pressure pulse signal was designed, and the pressure sensor module, motor drive module and low-power design of the downhole control system were described. The results of indoor and field tests showed that the pressure wave generated by the downhole adjustable switch was feasible as a means of wireless data transmission. The field test results show that the bidirectional wireless transmission system was effective, and its reliability and stability were also verified.

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