Intelligent Measurement and Adjustment of Layered Wells
Achieve Precise Water Injection and Improve Measurement and Adjustment Efficiency

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Abstract. The conventional layered water injection well test uses the wire and cable connection method. During the test, it is necessary to repeatedly drop and remove the test instrument and tool, use the test tool to detect the flow, and use the fishing plug to adjust the water nozzle. The deployment efficiency is relatively low. The intelligent measurement and adjustment system for layered wells is powered by cables to achieve real-time signal transmission. It has online sealing, nozzle-free fishing, continuous adjustment, real-time direct reading of test data, real-time monitoring of layered deployment parameters, shortening test deployment time, and improving with the advantages of measurement and adjustment efficiency and accurate water injection, field tests show that the intelligent measurement and adjustment system for layered wells has good application and promotion value.

Key words. Intelligent measurement and adjustment; improve measurement and adjustment efficiency; accurate water injection.

1. Introduction
With the deepening of oilfield development, the effect of oilfield waterflooding development becomes worse, and the inter-layer contradictions in oilfield waterflooding development become prominent. For an oil field with many oil-bearing layers, serious inter-layer, inter-layer, and planar heterogeneity, due to the large differences in the geological characteristics of each layer, this difference causes different water absorption indexes between the layers, usually water is not It enters the oil layer proportionally, so stratified water injection technology must be adopted. When the water injection amount is allocated to each layer in turn, due to problems such as inter-layer interference, each layer needs to be repeatedly deployed for a long time to reach the expected goal. The deployment efficiency is relatively low. If the inter-layer interference is serious, we may not be able to complete the dispensing task. Therefore, it is a major problem for layered water injection to select a suitable water injection method for layered water injection. The application of the intelligent measurement and adjustment water injection system for layered wells can effectively improve the layered test efficiency and water injection quality and reduce the test system personnel and equipment Put in.
2. Status of oilfield stratified testing process

2.1. Steel wire testing process, flow test nozzle, large workload and low deployment efficiency

The steel wire connection flowmeter tests the layered water volume. When it is connected to the fishing device for fishing, feeding plugs and water nozzles, it must be repeated many times layer by layer. Due to the large adjustment workload and high labor intensity, the interlayer interference test cannot be used. For its online monitoring, this test is difficult to achieve the requirements of accurate water distribution.

2.2. The cable test process measurement and adjustment linkage is visual and direct reading, and the data cannot be continuously monitored

The cable is put into the tester and connected with the adjustable plug. The ground control system transmits signals through the cable. The signals are displayed in the form of numbers and curves. The tester measures the current parameters such as current flow, temperature, and pressure in real time and performs water flow. Adjust until the requirements of the geological plan are met. However, there are obstacles, stuck cards, and inadequate connection during measurement and adjustment. After the measurement and adjustment are completed, the measurement and adjustment instrument is started and cannot be permanently monitored. When the water injection pressure changes and the water injection volume changes, the adjustment cannot be performed in time.

3. Intelligent measurement and adjustment process for layered wells

In 2014, our factory cooperated with Sichuan Science City Jiuli Electronics Co., Ltd. to develop a layered well intelligent measurement and adjustment water injection system. The surface operation control software monitors and displays the flow, pressure, and temperature data of each layer in the well in real time. The flow measurement can be adjusted and adjusted by human intervention to achieve precise water injection.

3.1. Working principle of layered well intelligent measurement and adjustment system

The ground communication controller is connected to the multi-layer underground intelligent water distributor through a cable. At the same time, the ground communication controller uses microwave + Ethernet to communicate with the server, and users can directly access the server through the local area network. The computer control system is used to set downhole instrument parameters, preset injection plans, query real-time measurement data and historical data, and operate the office computer for hierarchical test deployment.
3.2. Composition of intelligent measurement and adjustment system for water injection well

The intelligent measurement and adjustment system for the injection well consists of an underground intelligent water distribution device, a ground communication controller, and a computer control system.

3.2.1. Smart water dispenser: The intelligent water distributor is the core of the whole system to complete the downhole measurement and adjustment function. Its main body mainly includes flow regulation module, flow test module, pressure test module, control circuit, power supply system and other parts. Among them, the flow regulating module is mainly composed of a motor, a limit mechanism, a sealing mechanism, a transmission system, and an adjustable plug (water nozzle).
The intelligent water distributor mainly completes the collection and processing of flow, pressure, temperature and other data, as well as controlling the motor and adjusting the water nozzle.

3.2.2. Adjustable spout. The adjustable nozzle is a key component for automatic flow adjustment. If the opening and closing of the water nozzle is not well controlled during the flow adjustment process, the error of the flow adjustment cannot be controlled, thereby affecting the performance of the water distributor.
3.2.3. Ground communication controller. The surface communication controller completes the communication with the downhole instruments, as well as the acquisition and processing of the uploaded signals downhole. The ground communication controller is designed with a high-speed single-chip microcomputer. The instrument sends a wake-up command to the water distribution unit through a cable, checks the historical measurement data of the intelligent water distribution unit, or monitors the current measurement data, and adjusts the working parameters so that it can be adjusted according to the allocation requirements the amount.

The main function of the ground communication controller is to display the current voltage, current value and adjusted voltage value, control the switch of the positioner, and perform two-way communication with the underground data communication device.

3.2.4. Computer control system. The computer control system is mainly responsible for collecting and processing the measurement data of the intelligent water distributor, and setting the parameters of the intelligent water distributor.

The main functions of the PC software are setting working parameters, playing back data, querying instrument parameters, real-time measurement, and flow adjustment.
3.2.5. System parameters

**Tab.1 System parameters**

| parameter name                                      | value                        |
|-----------------------------------------------------|------------------------------|
| Ground communication controller size(mm)            | 380×280×150                  |
| Maximum outer diameter of intelligent water distributor(mm) | Φ114                        |
| Passage diameter of inner flow channel of intelligent water distributor(mm) | Φ46                         |
| Intelligent water distributor length(mm)            | 1200                         |
| Net weight of intelligent water distributor(kg)     | ≈40                          |
| Ground communication controller power supply(v)     | 20~75                        |
| Intelligent water distributor can automatically measure the number of times | Unlimited                   |
| Adjustable plug motor battery power supply(v)       | 50v                          |
| Adjustable plugging motor working current(mA)       | 30~50                        |
| Working temperature of intelligent water distributor (℃) | ≤90                         |
| Working current of intelligent water distributor(mA) | 24~30                        |
| Working pressure of intelligent water distributor (Mpa) | ≤40                         |
| Measurement parameters                              | Flow rate, tubing pressure, casing pressure, temperature, humidity |
| Flow measurement range                              | 0~60m³/d                    |
| Flow measurement accuracy                           | ≤±1.0%                      |

3.3. Remote data transmission

There are two ways of remote data transmission: GPRS and microwave. The advantages and disadvantages of the two methods are as follows:
| Types of                | GPRS                                                                 | microwave                                                  |
|------------------------|----------------------------------------------------------------------|-----------------------------------------------------------|
| Environmental adaptability | Only use the place with GPRS signal                                 | No other network signal requirements                      |
| Transmission rate       | One-way delay is about 1 second, and the amount of data transmitted in a single time is limited | The transmission delay is small, the bandwidth is wide, and a large number of transmissions can be carried out |
| Maintenance cost        | Card annual fee, cloud server annual fee                            |                                                            |
| Convenience             | Can only use the Internet (Internet), that is, users need to access the Internet to access data | Can be directly connected to the oilfield intranet, that is, users can directly use the oilfield LAN to access data |

3.3.1. Microwave method. The biggest advantage of the microwave method is that the maintenance cost is low, and the instrument can be queried and controlled directly through the oil field LAN. This method also reduces the risk of data leakage without going through the Internet. At the same time, the transmission bandwidth is large, which is convenient for collecting other data in the future.

3.3.2. GPRS method. The biggest advantage of GPRS is simple installation. The disadvantage is that it can be used where there is a GPRS signal. It can only send data to the server through the external network (Internet), that is, the user can only view and operate the instrument through the external network, and its transmission delay is large and the data volume is small. Is not conducive to expansion, maintenance trouble, the number card can not be owed to stop.

3.3.3. Server and web client. The server uses an ORACLE database. Users can access the server through the webpage to achieve the purpose of querying and controlling the instrument.

4. Field test results

4.1. Realize online inspection for sealing function

4.1.1. Check the pressure of the front section when sealing

4.1.2. Check for tightness. Open the partial II water nozzle, close the partial I and partial III water nozzles, and open-close-open the ground to check the seal.

   (1) Read partial II pressure detection data.
   (2) Read partial I horizon pressure detection data.
   (3) Read partial III horizon pressure detection data.
From the three-layer curve, it can be seen that the pressure of the formation (behind the mouth) of the partial II layer and the pressure of the formation (behind the mouth) of the partial I and III layer do not coincide, and the packer is sealed.

4.2. Implement intelligent measurement and adjustment functions

China’s 61-inclined 301 well was installed and tested successfully on April 24, 2016. Due to cable joint problems, the pipe string was taken out on May 26, 2016, and it was re-inserted on July 7-8, 2016 and was on the ground on July 11. The remote monitoring system is successfully connected. As of August 25, 2016, wireless automatic measurement and adjustment.

Basic Situation of Well 61-Oblique 301

(1) Partially dispense 20m3 to complete the dispense, the opening of the nozzle is 6.0mm, and the pressure difference is 3.4MPa.

(2) Partial II is filled with 30m3, and the actual water injection is 2m3 underfilled, which basically does not absorb water. The opening of the nozzle is 12.0mm, and the pressure difference between the front and rear is 0-0.1MPa.

(3) Partial III was filled with 15m3 of water and 16m3 of water was injected. The nozzle opening was 4.3mm, and the pressure difference between the front and rear was 2.0MPa.

Analysis: The reason why partial II does not absorb water is that the formation pressure is high and the water injection oil pressure cannot be increased due to the overlying rock pressure.

5. Conclusion

The first is high measurement accuracy and accurate test data. With intelligent water distributor as the core, it integrates multi-parameter measurement of flow rate, tubing pressure, casing pressure, temperature, and humidity, and adopts electromagnetic flowmeter to measure in layers. The measured flow rate is the actual injection volume flow rate of each layer.

The second is to achieve online monitoring, real-time controllable and readable parameters. Intelligent allocation according to the dispensing plan, the measurement data is automatically saved, the deployment process does not require too many people to participate, the layered water is intuitively allocated, the nozzle is continuously adjustable, and the packer is checked online.

The third is a high degree of automation, which effectively improves testing efficiency. Continuously track injection parameters, truly reflect changes in formation water absorption performance and pressure, and plan changes are adjusted immediately.

Fourth, the shape of the water distributor is the same as the conventional conventional water distributor. The pipe string adopts washable packer, and the minimum diameter of the water distribution pipe string is 46mm, which can pass various test tools.

The fifth is to realize the online visual function of the network client. Microwave + Ethernet is used to directly access the server through the LAN, and the working status is clear at a glance.

Sixth, the production cost is high, and only a single water distribution instrument is more than 50,000 yuan, which needs to further reduce costs.

Seventh, compared with conventional water nozzles, it is relatively difficult to unblock the water nozzle of the intelligent water dispenser, and serious work needs to be solved.

Eighth, the wired measurement and adjustment system's line cables, the life of the electronic components of the underground water distributor, and the stability of the underground instrument work need time to verify, and the ground electrical equipment and supporting tools need further specifications.

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