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The Development of Real-time Detection and Wireless Transmission System of Drilling Parameters in HDD Reaming Hole

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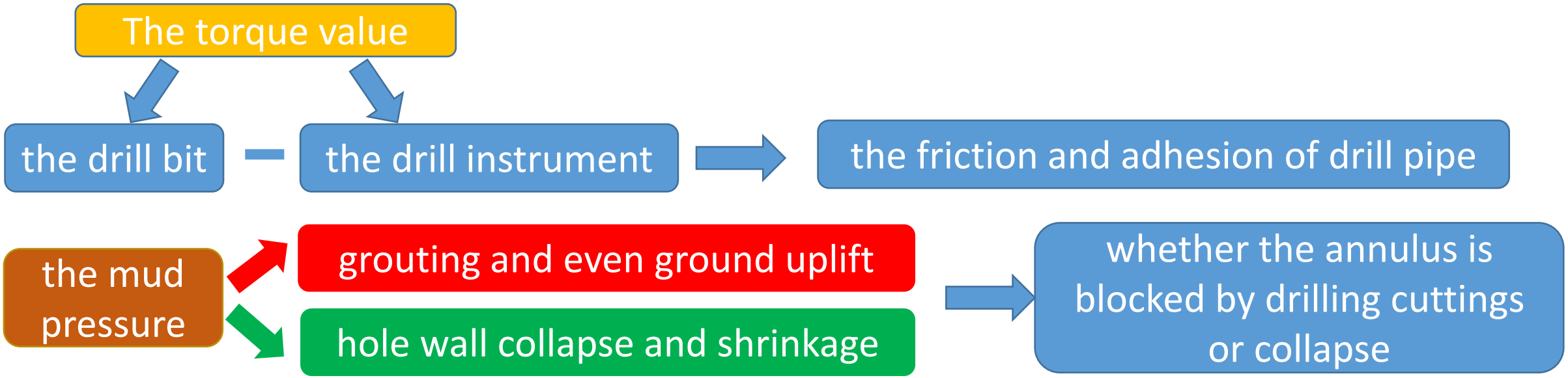
Hole reaming, one of the main processes of HDD, determines the efficiency and success of the whole project.

In the reaming operation, the torque of drill bit and the pressure of mud at the bottom of hole are the most important control parameters to be determined.



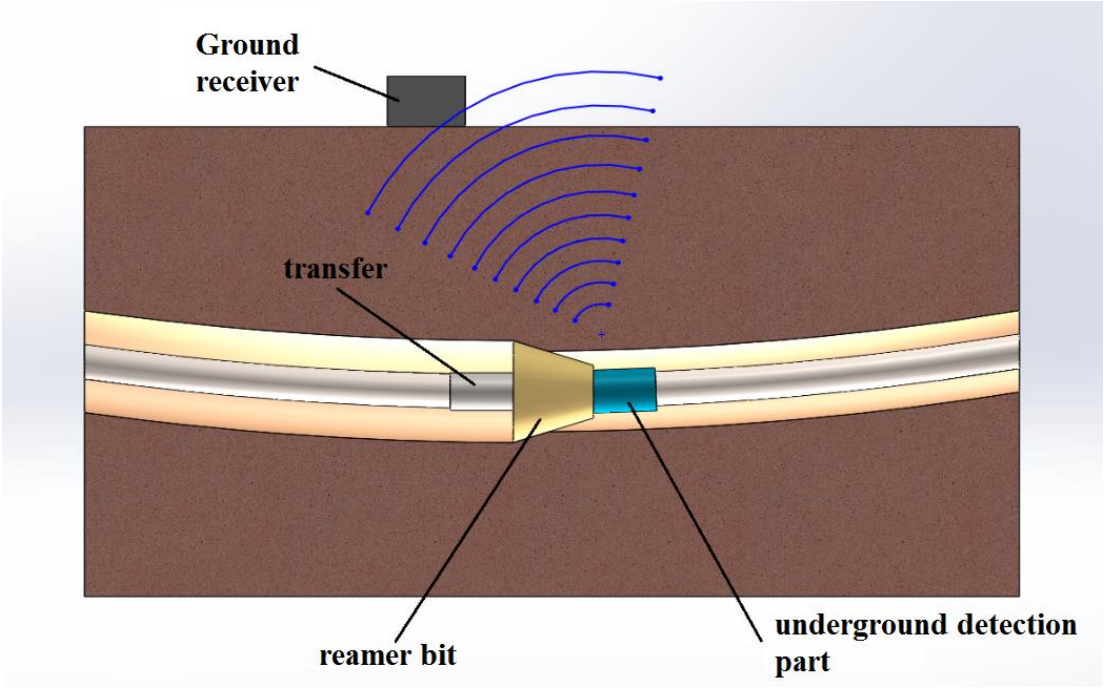
However, in the practical reaming construction, the bit torque and the mud pressure at the bottom of the hole cannot be accurately obtained, so it is invisible and impenetrable under the current technical level.

By determining the detection and installation method of various parameters, designing and process some subsurface detection transmitting short sections and surface VLF signal receiving equipment, and taking certain measures to reduce signal interference, real-time and real related data can be obtained on the surface. Therefore, it is of great practical significance to develop a device to automatically detect the mud pressure and bit torque at the bottom of the hole.

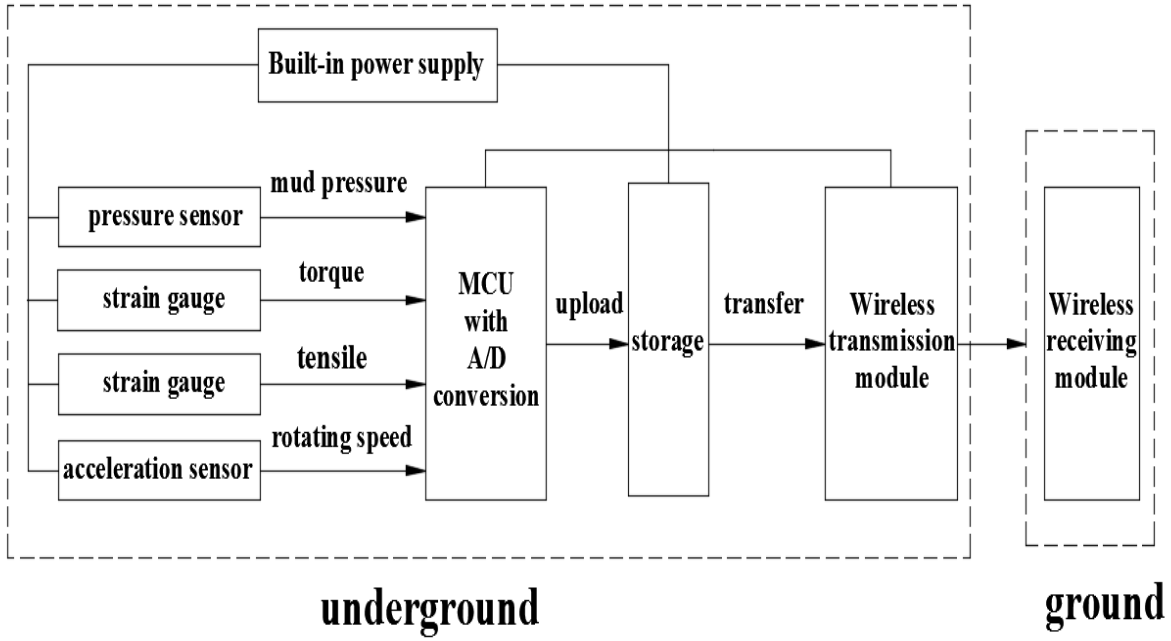
2.PRINCIPLE DESIGN

2.1 Overall system design

Schematic diagram of system working principle



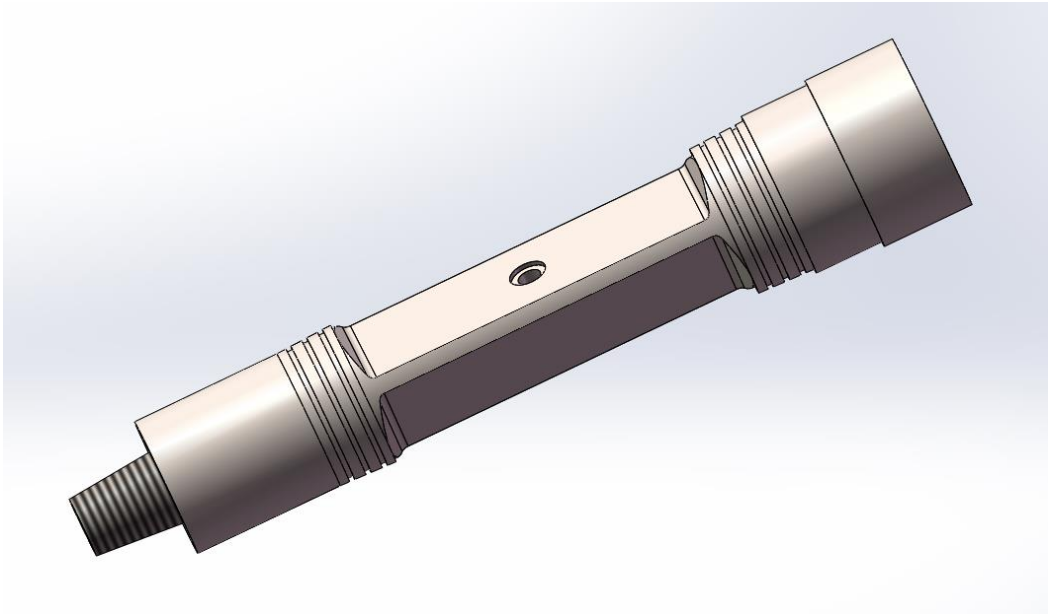
Schematic diagram of detection principle

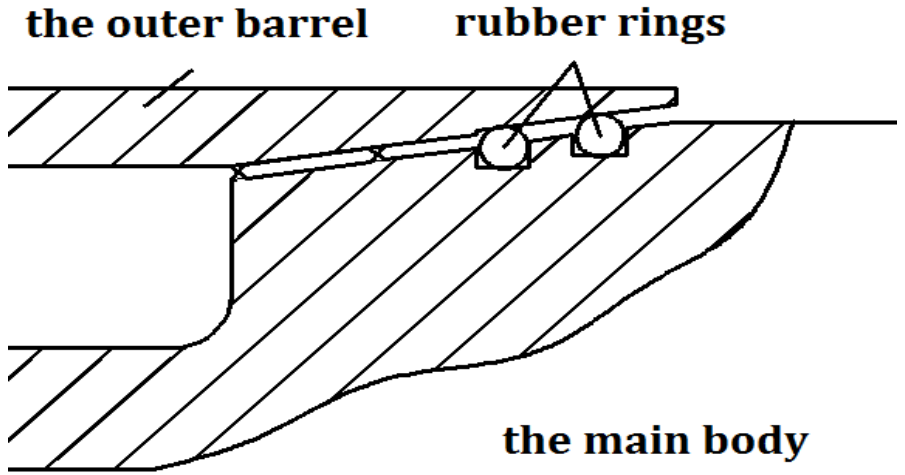


2.PRINCIPLE DESIGN

2.2 Mechanical design of underground detection part

The underground detection part consists of two parts: the main and the outer barrel. The two parts are connected by thread and sealed by conical surface and multiple rubber rings, in order to prevent mud from entering and protect the sensor and circuit board.





[1]

In view of the circuit board and sensor installation convenience, the main body of the underground part is designed as a three-valve structure, and its strength is checked by theoretical calculation and software simulation.

$$W_t = \frac{\pi D^3}{16}\left(1-\frac{d^4}{D^4}\right)$$

$$\tau = \frac{T}{W_t}$$

W_t-torsion resistance interface coefficient;
τ-allowable stress;
T-torque;
D-outside diameter of pipe;
d-inner diameter of pipe.

2.PRINCIPLE DESIGN

2.2 Mechanical design of underground detection part

Take the drill pipe inner diameter and outer diameter of 57mm (2.24inch) and 73mm (2.87inch) respectively

$$\tau_1 = \frac{16T_1}{0.00024441\pi}$$

τ_1-allowable stress; T_1- maximum torque that the pipe can bear.

Take the pipe's thinnest part inner diameter and outer diameter of 25mm (0.98inch) and 73mm (2.87inch) respectively

$$\tau_2 = \frac{16T_2}{0.00038367\pi}$$

τ_2-allowable stress; T_2- maximum torque that the pipe can bear.

If the material used for the underground part is the same as that of the drill pipe, the maximum torque that the underground part can bear is 1.57 times that of the drill pipe.

$$\frac{16T_1}{0.00024441\pi} = \frac{16T_2}{0.00038367\pi} \qquad \frac{T_2}{T_1} \approx 1.57$$

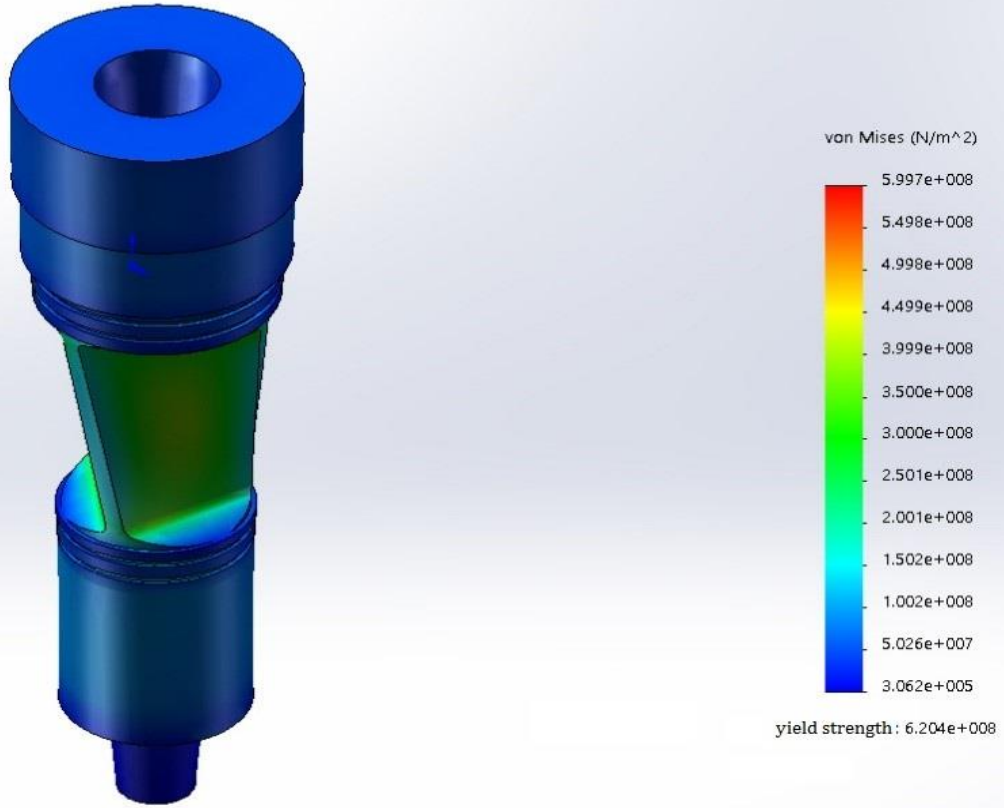
2.PRINCIPLE DESIGN

2.2 Mechanical design of underground detection part

[1]

Using Solidworks for stress analysis

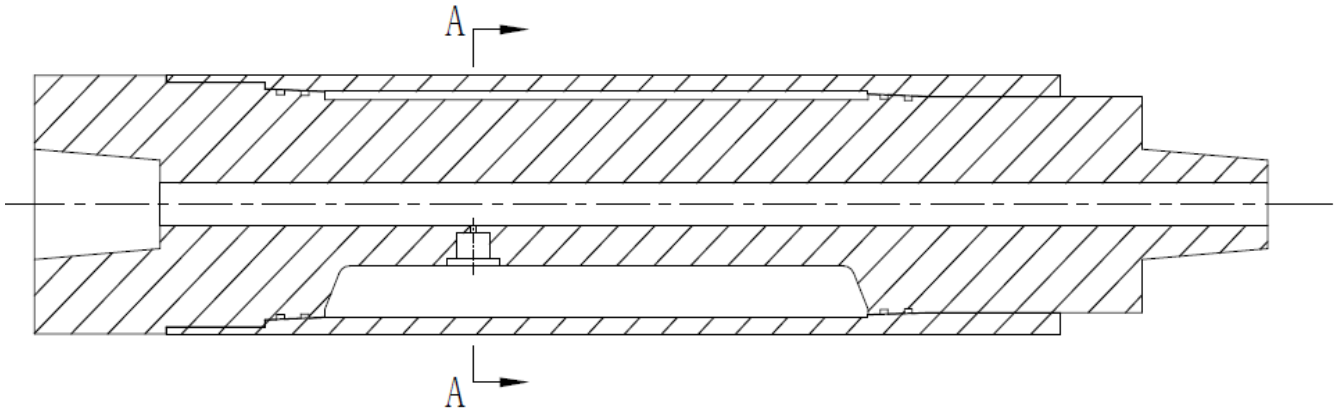
The selected material‘s yield strength is 6.20422e+008 Newton per square meter。
350000 Newton pulling force and torque of 20000 Newton meter (14751Ft-lbs) are applied.
The maximum stress is 5.99713e+008 Newton per square meter, which is smaller than the material's yield strength.

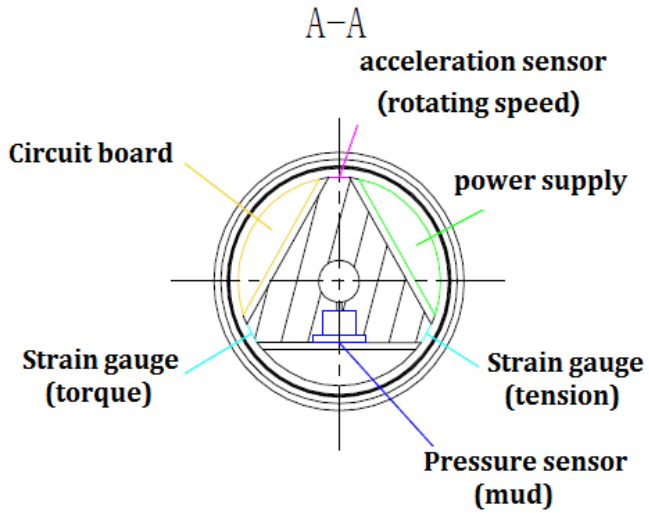


2.PRINCIPLE DESIGN

2.3 Circuit board and sensor installation

[1]





[1]

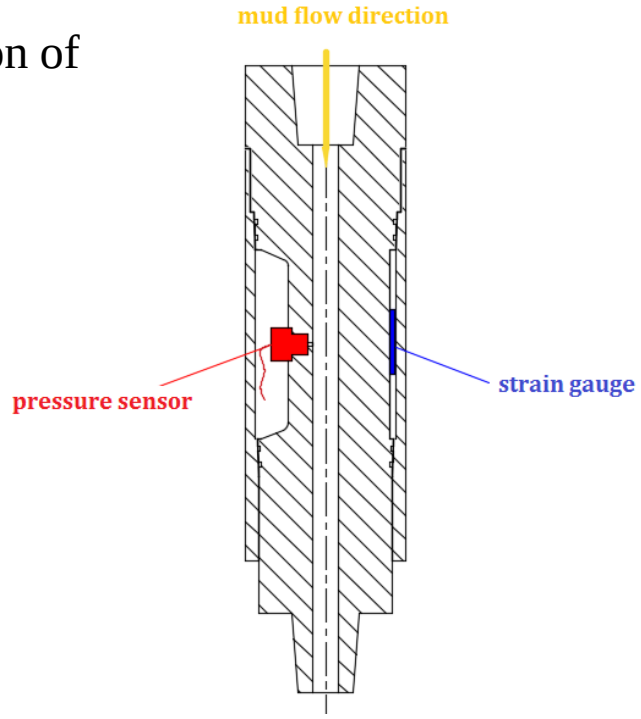
2.3.1 Mud pressure detection

In many kinds of commonly used pressure sensors, the direct measurement of pressure is generally complicated, so the measurement of pressure can be converted into the measurement of resistance of strain wire.

Considering the limited space for installation, a customized pressure sensor is adopted to further compress the circuit board space, remove the outer cylinder, and protect the circuit board with high-strength sealing glue.

2.3.1 Mud pressure detection

the principle and installation of mud pressure detection



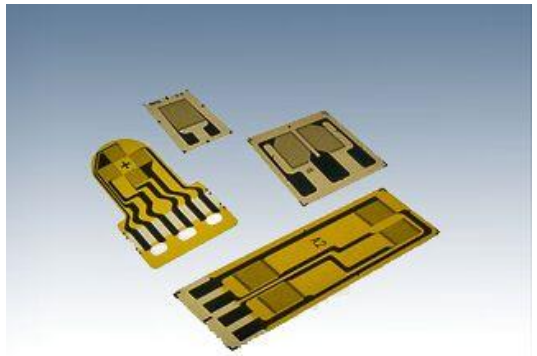
Special pressure sensors were put into the autoclave for pressure test, and the pressure was stabilized for 30min after the pressure was added to 6Mpa (870psi).

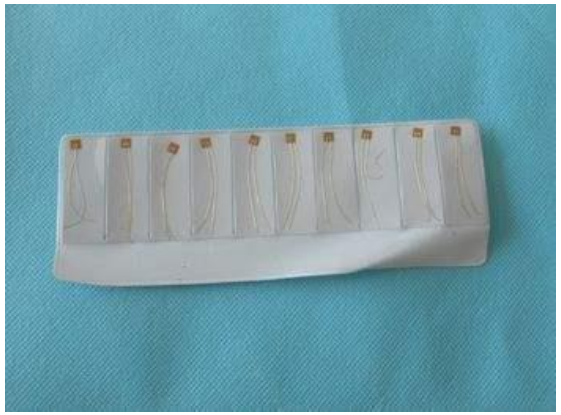
[1]

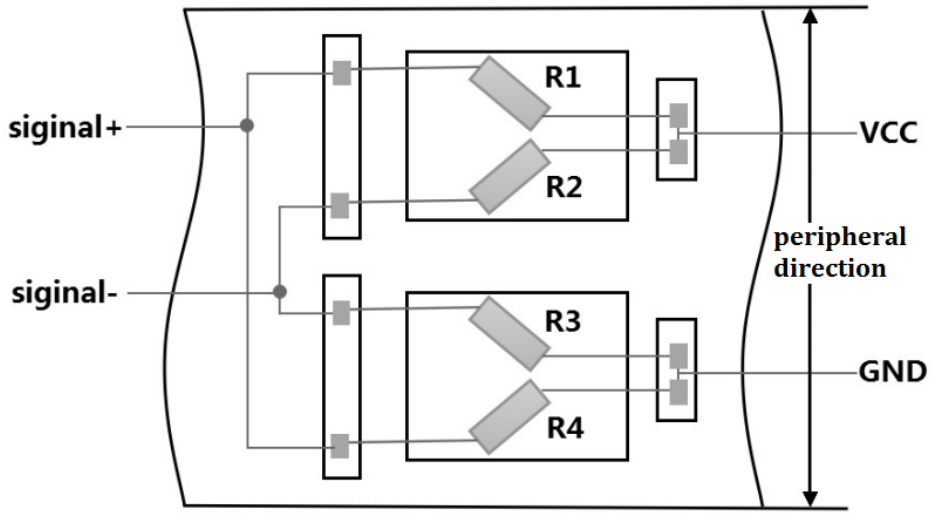
2.3.2 Torque detection

2.3.3 Tension detection

The feasible method proposed is to use strain for measurement, and small deformation of strain gauge will occur under torque, resulting in changes in resistance.





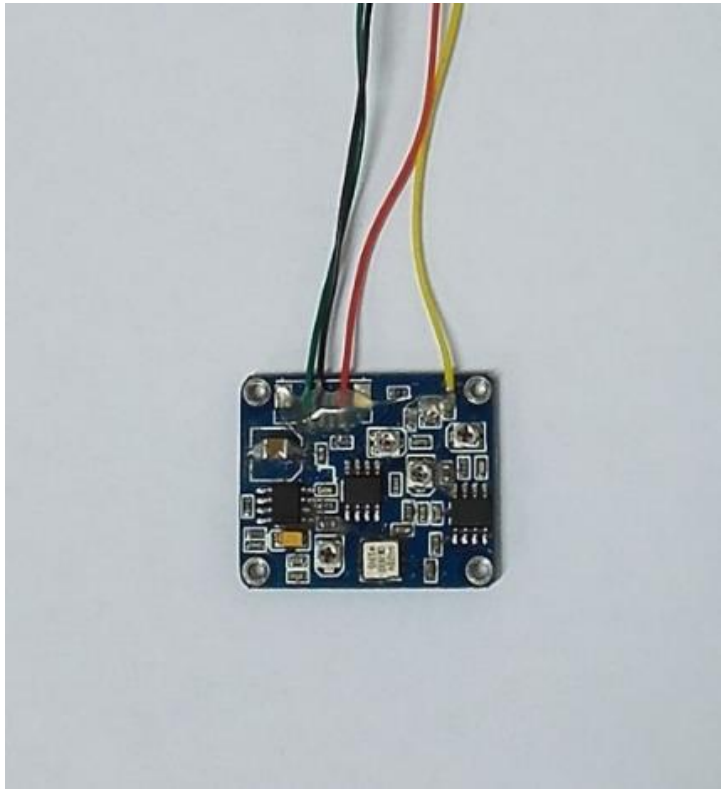


When measuring torque, the strain gauge should be paste along the axis of the measurement part at a 45° angle and connected to the full-bridge circuit for measurement。

[1]

2.3.4 Rotating speed detection

The rotating speed is measured by the acceleration sensor without angle interference. At the same time, the trenchless construction drill pipe is mostly in horizontal or near-horizontal state, and the drill pipe tends to bend and deform in the direction of gravity. Every time the drill pipe turns a circle, the sensor position will change periodically (from the highest to the lowest reciprocating change), which can simplify the detection method and reduce the interference.



[1]

2.3.5 Circuit board and sensor layout

In order to meet the installation requirements, the size of the circuit board was controlled at 100mm*30mm (3.937inch*1.181inch).

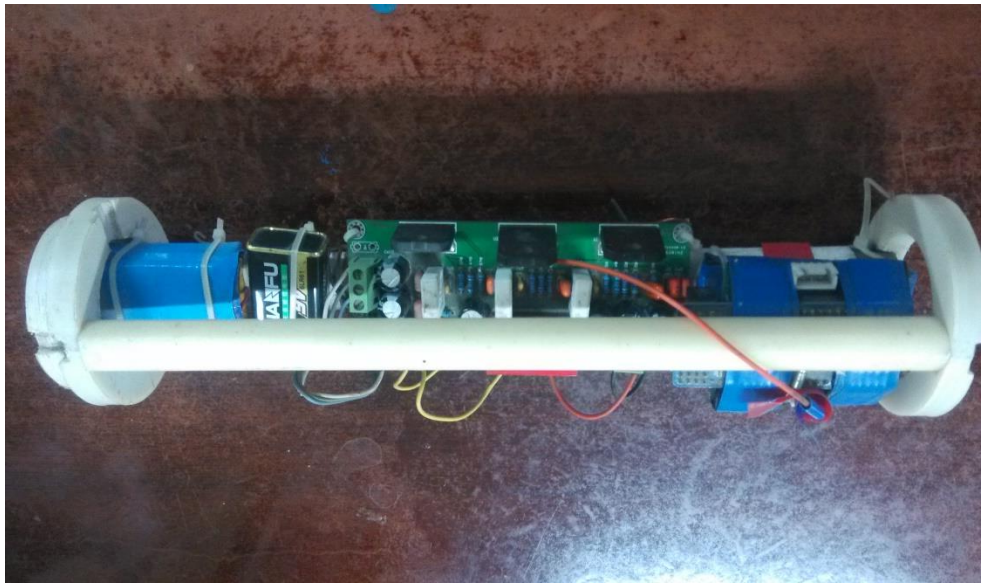
2.PRINCIPLE DESIGN

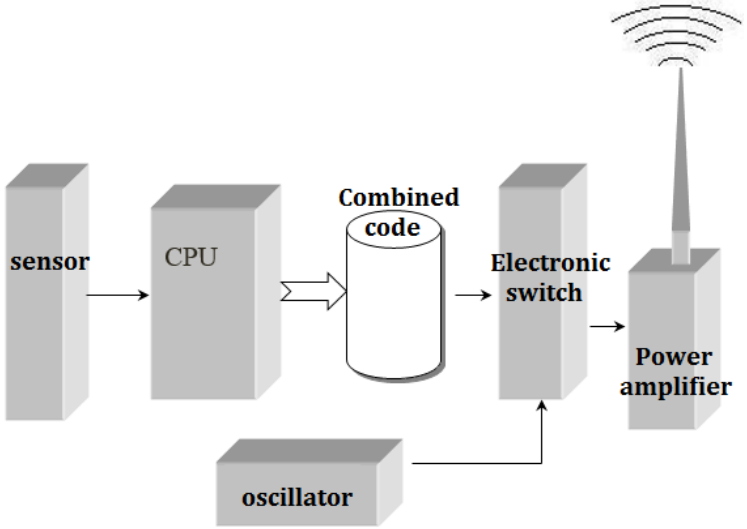
2.4 Wireless launch and receive

The wireless transmission of HDD underground signals belongs to the ground-penetrating communication system, which takes the earth as the transmission medium and uses the principle of electromagnetic wave penetration. When the frequency of electromagnetic wave is high, its wavelength is short and ability of propagation in heterogeneous strata is poor, the phenomenon of refraction and reflection will happen underground. The electromagnetic parameters such as dielectric constant and conductivity of soil changes with the change of moisture content, which make the channel characteristic of electromagnetic wave propagation in the process of unstable. Therefore, the main electromagnetic wave frequency range is 3~30 kHz (VLF). The wireless transmitting and receiving system mainly consists of underground launch module and ground receiving module.

2.4.1 Underground transmitting module

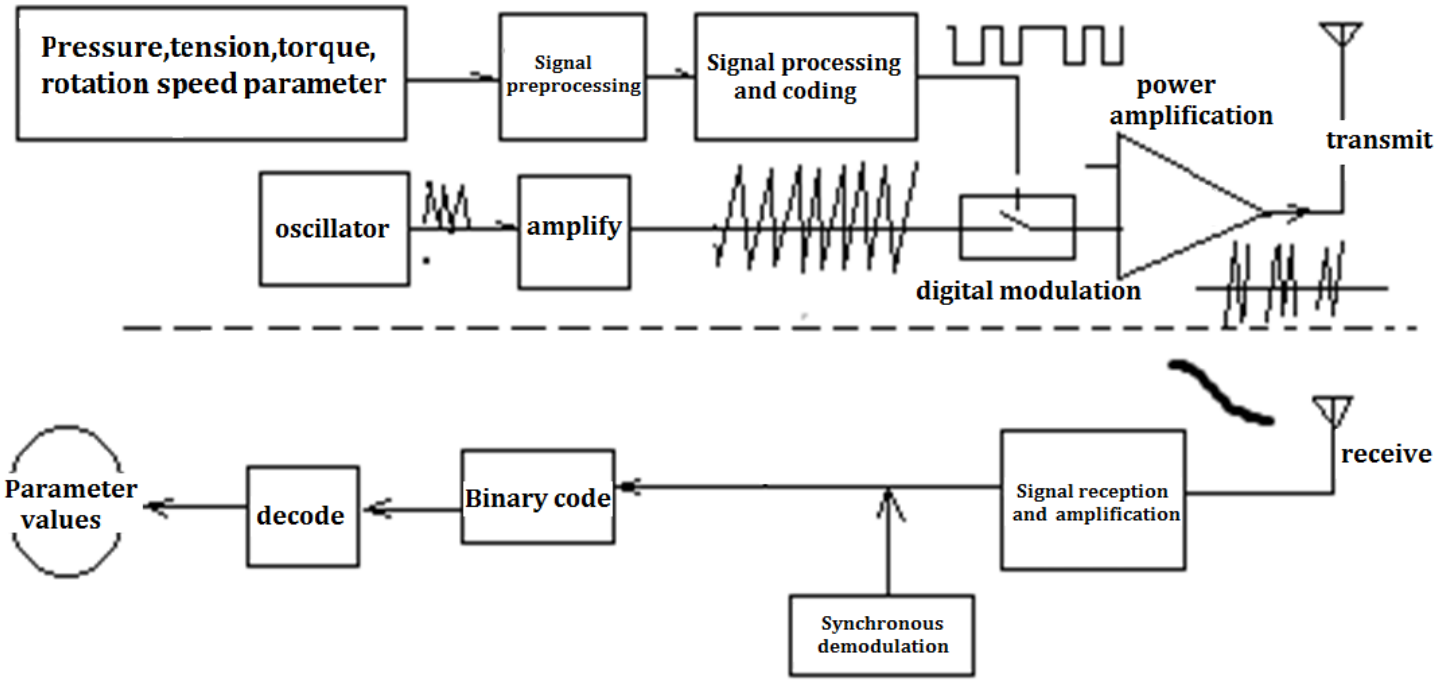
The detection signal of sensors will be preprocessed by the transmitting module, and then through the analysis of the CPU processing, finally become a signature combination of signal and the angle signal by the baud rate of serial port in a certain (set to 150 BPS) string of code output, the signal is composed of coding signal that according to certain rule. ASK modulation is adopted to oscillate the signal. The modulation wave, the power of which is amplified, emitted by the coil inside the probe.





[1]

2.4.1 Underground transmitting module

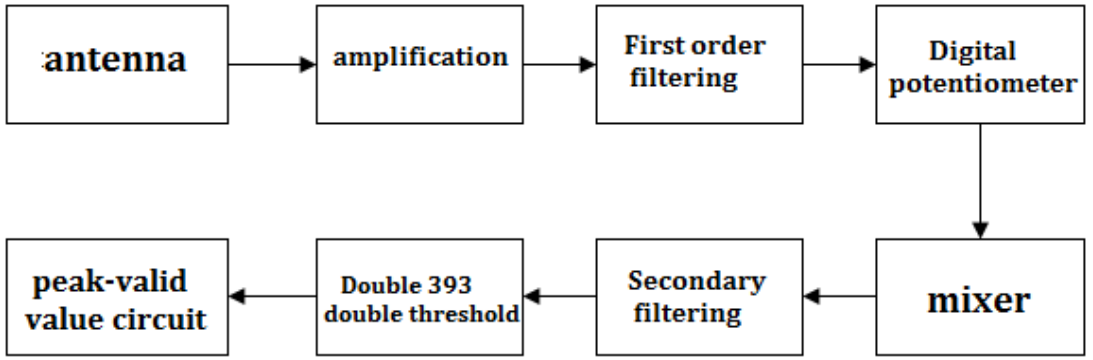


According to the method of parameter detection, the modulated transmission method is used. After receiving the signal, the receiver will amplify, filter and shape the signal to obtain the preprocessing signal. Part of the circuits demodulate the signal and restore the modulated signal to obtain the parameters in the hole.

[1]

2.4.2 Ground receiving module

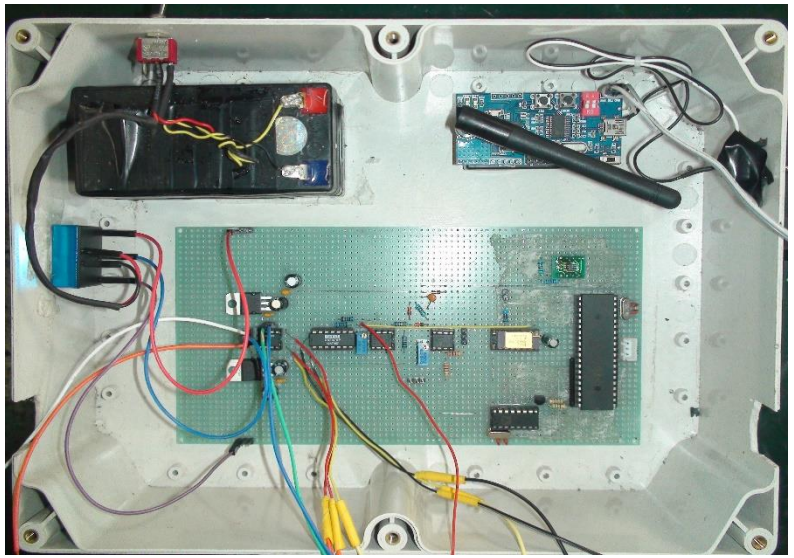
The receiving module circuit is composed of antenna, signal amplifier, filter, mixer, peak-valid value circuit, etc. The signal will be processed and output according to the following circuit procedure.

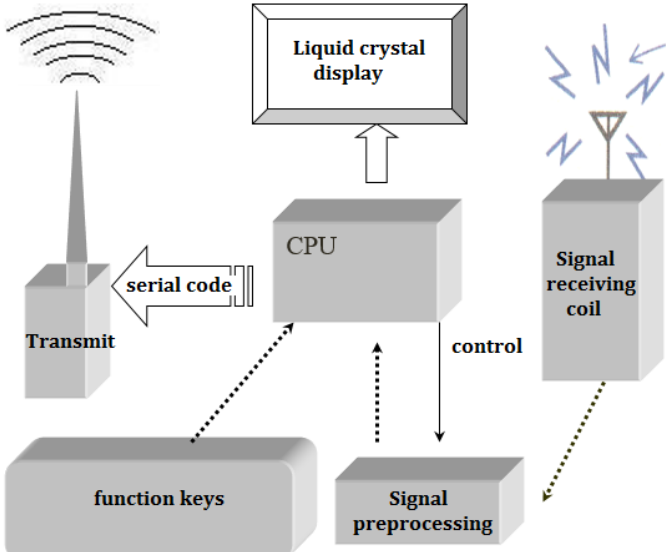


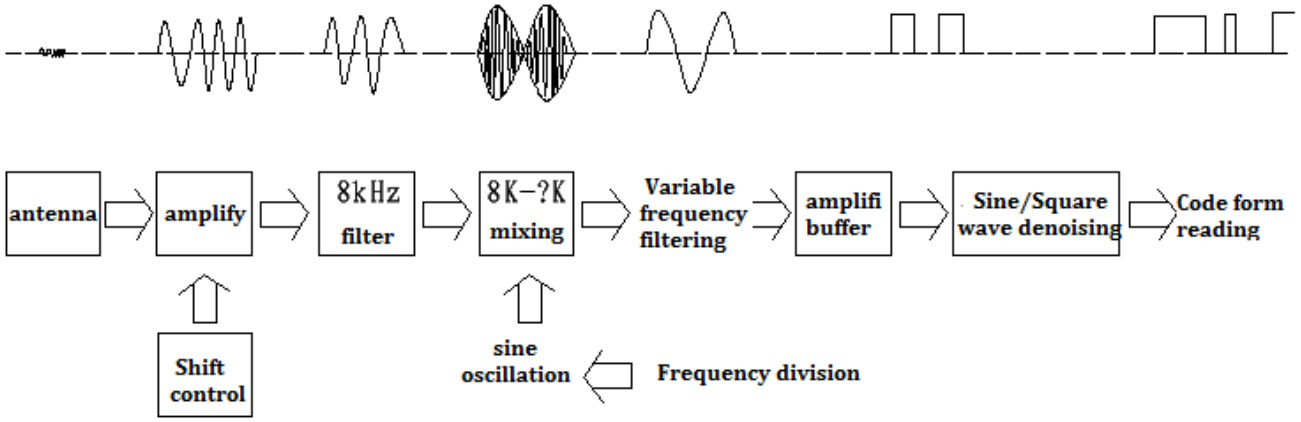
[1]

2.4.2 Ground receiving module

The underground wireless wave is transmitted to the ground receiving module through the antenna. After many tests, 7 strands of enameled wire with a diameter of 0.07mm (0.00276inch) are adopted, and the simple stranding wire winding coil with turns between 400 and 480 is used as the receiving antenna to achieve better receiving capacity. IN114 amplifier is used for the first stage amplification, UAF42 active filter is used for the first stage filtering, LM-1496 mixing circuit is selected, and a new RMS chip AD536 is adopted.



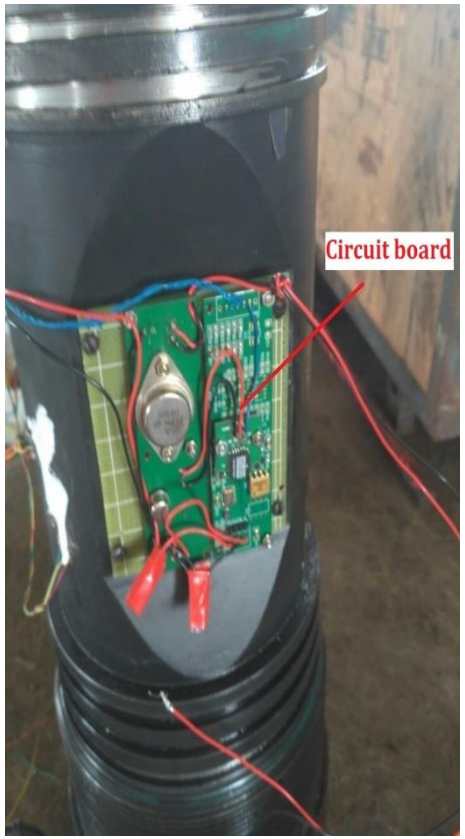


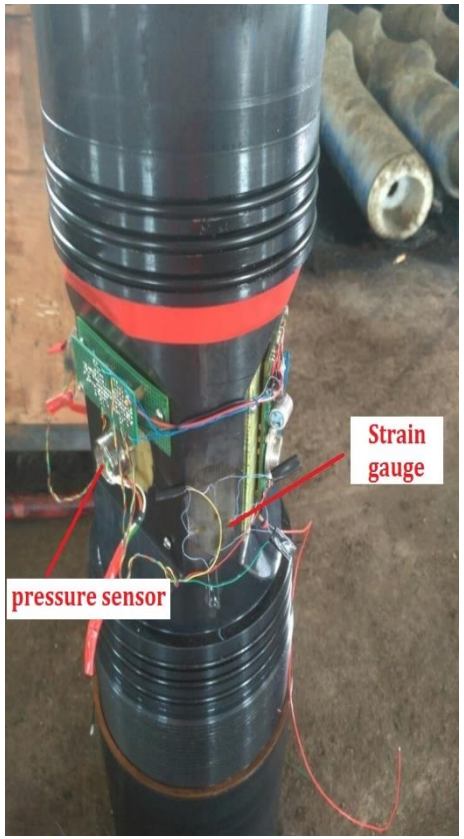


3. TEST

[1]

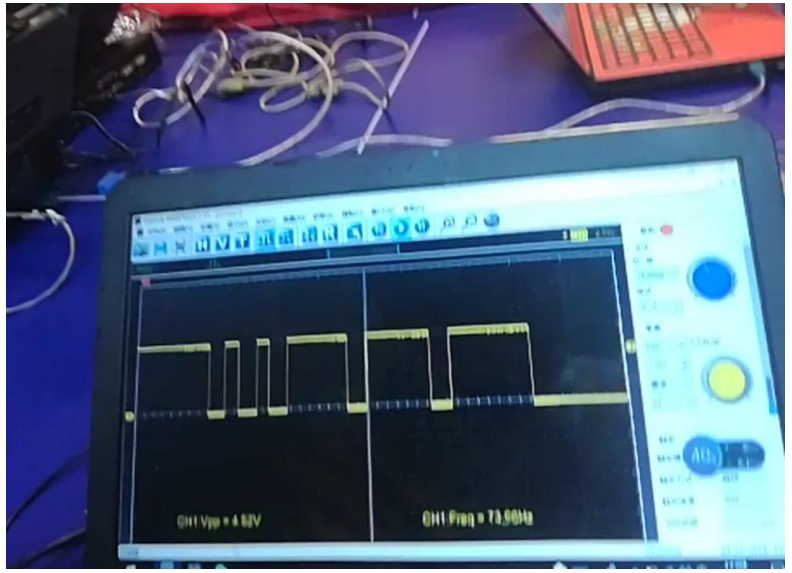
The structure and testing principle of the underground detection part were tested in the field, and the testing results were basically consistent with the original testing methods and instruments in the field.





3. TEST

An indoor wireless signal transmission effect test and inspection system was set up. The experiment results show that the transmitter power is sufficient and the anti-interference effect of the receiver is good. The total delay of electromagnetic wave transmission is about 24s, and the decoding circuit is correct. By comparing the electrical signals of electronic instruments and display instruments, it is proved that the wireless transmission of the collected signals of circuit boards are realized.



4. CONCLUSION

The development of automatic detection system can make sure that direct detection of torque, axial force and mud pressure near the drill bit at the bottom of the hole is realized in HDD construction. The detection signal is encoded, modulated and transmitted to the surface receiver for demodulation through VLF radio electromagnetic waves. It can solve the problem that the real working condition in the hole cannot be accurately grasped only by surface sensors and instruments, provide basis for scientific judgment and reasonable control of construction parameters in the hole during HDD construction to ensure the safety and efficiency of the project.

Thanks!