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Real - time Dynamic Control Analysis Technology of Closed Underbalanced

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Abstract: In the deep oil and gas exploration hydrogen sulfide and other harmful gases are found, which seriously hinder the development of such strata. Airtight underbalanced drilling technology for the sulfur-bearing formation to provide efficient exploration and development, It can track and evaluate the under voltage window in the drilling process in real time and control the under voltage value to ensure the safety of drilling. In view of this, this paper is based on the dynamic control model of airtight underbalanced wellhead, And through the study of wellbore pressure relation and wellbore pressure control principle, and propose a set of airtight underbalanced remote real-time dynamic control analysis technology, Using C # language complete the development of dynamic control analysis system of airtight underbalanced drilling, and realize the drilling site hydrogen sulfide safety monitoring and bottom hole pressure remote real-time monitoring and reduce drilling accidents, to ensure the safety of drilling construction.
Keywords: airtight underbalanced drilling, bottom hole pressure monitoring, wellhead back pressure dynamic control

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1. INTRODUCTION

With the growing demand for oil energy and the depletion of oil and gas reservoirs, oil and gas development is gradually shifting towards "deep, sea, low and non". With the further deepening of oil and gas exploration, With the further development of oil and gas exploration, the harmful gas [1], such as hydrogen sulfide, has been found in deep oil and gas reservoirs in china. In the early 1980s, China's proven hydrogen sulfide natural gas accounted for one-quarter of the national gas reserves, and at present, 60% of China's gas fields are sulfur-bearing gas fields, of which 80% of Sichuan's total natural gas production is sulfur [2]. In order to ensure the safe and efficient exploration and development of sulfur-bearing strata, it is necessary to form a targeted technology development method, in which airtight underbalanced drilling technology is an important research direction. Therefore, based on the research of airtight underbalanced technology, this paper has developed a real-time dynamic control analysis system for airtight under balanced drilling, which is of great significance for underbalanced safety drilling of sulfur-bearing strata.

2. AIRTIGHT UNDERBALANCED BOREHOLE PRESSURE SAFETY MONITORING

The use of underbalanced drilling technology in the drilling process is conducive to the protection of the reservoir, in which the setting of the reasonable under voltage is the key of the whole underbalanced drilling [3], If the under voltage value is too high, it will cause overflow and wellbore pressure instability, sulfur-containing formation in the hydrogen sulfide overflow caused serious security incidents, therefore, to control the reasonable under voltage and to ensure that no well control out of control. The most important process in a closed underbalanced technique is the ability to quickly and accurately control the bottom hole pressure. For the dynamic control analysis of the bottom hole pressure, it is necessary to design and evaluate the various control parameters of the underbalanced drilling safety drilling, But limited by the condition of the reasons, in this paper only the control parameters wellhead back pressure were studied and analyzed. Through the ground instrument for pressure, flow, conductivity and gas monitoring whether the current drilling process of the overvoltage is reasonable, and then according to the principle of closed underbalanced drilling bottom hole pressure control [4], through the study of wellhead back pressure control theory and model, design and develop a dynamic control analysis system, Combining with the field control system for dynamic control of bottom hole pressure,to maintain a reasonable under voltage threshold, and finally form a set of airtight underbalanced drilling real-time dynamic analysis system.

3. THE PRINCIPE OF DYNAMIC CONTROL FOR AIRTIGHT UNDERBALANCED DRILLING

3.1 Airtight underbalanced bottom hole pressure control theory

The key to airtight underbalanced safe drilling is to maintain a reasonable under voltage value by controlling the bottom hole pressure. When the bottom of the pressure is too small, it can’t effectively control the formation of gas intrusion, so that the wall is easy to instability, well blowout, resulting in drilling fluid can’t effectively carry rock and then produce wells are not clean and other issues; When the bottom of the pressure is too large, not only makes the oil and gas reservoirs are destroyed, which is a serious waste of resources, and even leakage and other underground accidents. Therefore, the need for real-time monitoring can affect the bottom of the pressure fluctuations in the parameters, through the combination of airtight underbalanced drilling technology and equipment research, and use the optimal monitoring parameters and control parameters to dynamically analyze the current bottom hole pressure, and then on the under voltage value of the timely and accurate adjustment and control to ensure that the bottom of the pressure to maintain a safe window within the scope [5].

3.1.1 Airtight Underbalanced Drilling Construction Process Wellbore Pressure Relationship:

$$p_F = p_p - p_m - p_a - p_t \tag{1}$$

Where the formation pressure p_p is the pressure of the subsurface fluid in the pores of the rock, and the hydrostatic pressure normally applied to the depth of the subsurface formation fluid is equal to the formation pressure there. Ground pressure p_t refers to the pressure required to overcome the friction required during the circulation and the wellhead back pressure. The pressure of the hydrostatic column p_m refers to the pressure generated by the gravity of the drilling fluid column. The annulus pressure p_a is generated by the circulation of the drilling fluid and is determined by the drilling fluid performance and the drilling fluid parameters.

3.1.2 Under voltage design generally need to follow the following principles:

(1) the bottom hole pressure should be higher than the formation collapse pressure, less than the formation pore pressure, so the under voltage value should be between the difference of the two pressure;

(2) under voltage value should not be set too high, too high will not only increase the cost of drilling fluid, and to increase the difficulty of the ground pressure control construction, separation of equipment separation capacity also put forward higher requirements;

(3) The stress of the negative pressure difference in the borehole wall should be lower than the reservoir strength, so as to avoid the stress damage of the reservoir.

(4) According to the formation of gas production to determine the size of the value of under voltage, the size of the value of the pressure should be measured with the formation of reverse growth.

According to the above control principle of bottom hole pressure and the design principle of under voltage value, combined with the control parameters of bottom hole pressure selected in the previous section, the control method of wellhead pressure is selected to control the bottom hole pressure.

3.2 Airtight underbalanced drilling back pressure control

3.2.1 Control of back pressure design method

The density of the drilling fluid must be reasonable in the safety drilling fluid density window, Figure 1 shows the safety drilling fluid density window and Wellbore pressure profile and back pressure indication, The left figure shows the safety drilling fluid density window (the figure is assumed to be pore pressure and fracture pressure curve), The right figure shows how to determine the safety pressure window between the two red lines, it is $\max(P_p, P_{cp}) \le P_{bh} \le \min(P_f, P_{Leak})$, Simplified as $P_p \le P_{bh} < P_f$; The minimum pressure window curve and the maximum pressure window curve extended to the wellhead, with the control of the pressure line in the A and B point intersection, the figure shows the intersection of two possible back pressure control possible range.

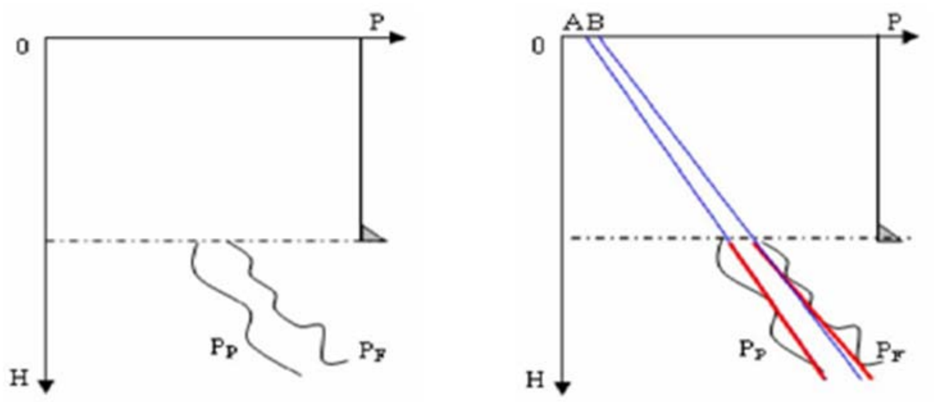

Figure 1 the safety drilling fluid density window and Wellbore pressure profile and back pressure indication

But the control of back pressure is negative situation is likely to occur. Figure2 shows two modes of calculating backpressure, the left figure shows a single gradient cannot satisfy the calculation of the safety pressure window, we only use the double gradient model to calculate the safety pressure window, as shown in the right figure:

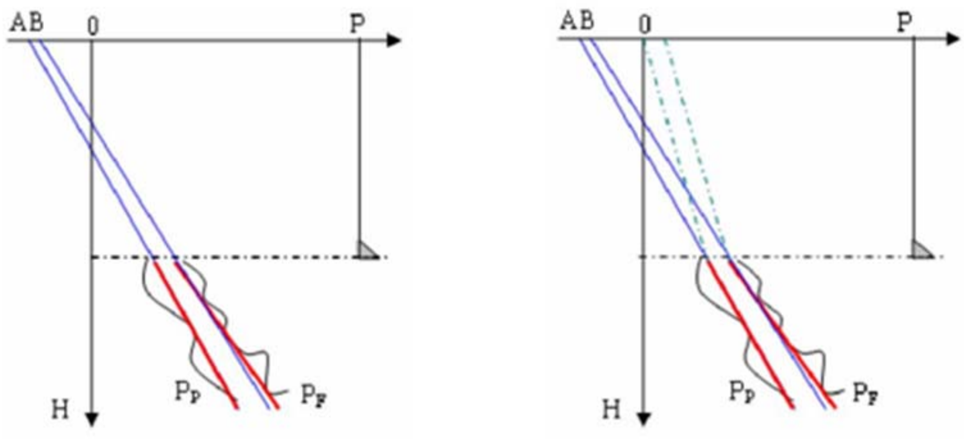

Figure 2 Well bore pressure profile and back pressure indication and Double gradient model to determine the wellbore pressure profile

For a narrow safety drilling fluid density window, if the static equivalent of the drilling fluid pressure curve is in the safety density window inside, during the cycle, due to the presence of cyclic friction, Figure 3 shows schematic diagram of dynamic pressure profile and schematic diagram of annular pressure profile control. The left figure shows the dynamic pressure curve goes beyond the safety window, and the right figure shows when the dynamic pressure curve is inside the safety density window, and the static pressure curve is lower than the formation pore pressure, there may be complicated drilling accidents such as well surging.

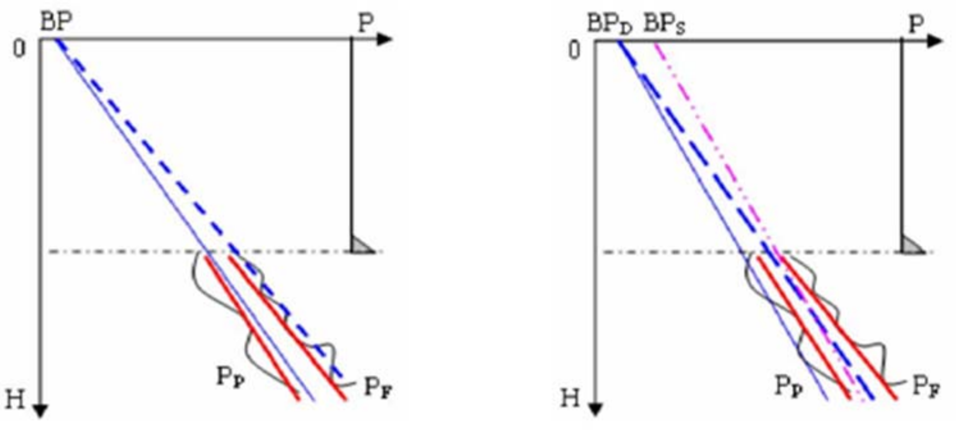

Figure 3 schematic diagram of dynamic pressure profile and schematic diagram of annular pressure profile control.

At this point, the dynamic pressure curve should be located within the safe density window, The formula is as follows:

$$P_p \le \rho_m gH + \Delta P_f + P_B \le P_f \tag{2}$$

here ρ_m is Gas - liquid mixture density, P_f is Cycle friction, P_B is Control back pressure.

When the circulation stops, the pressure is applied to control the pressure curve in the safe density window, The formula is as follows:

$$P_P \le \rho_m gH + P_{BS} \le P_f \tag{3}$$

From equations 2 and 3 can be obtained, and ΔP_{sf} is the pressure change value of the gas slippage rise.

$$P_{BS} = \Delta P_f + P_B + \Delta P_{sf} \tag{4}$$

After the safety drilling fluid density window is determined, the corresponding control back pressure values are calculated using the theoretical analysis of the under fill pressure of the underbalanced borehole drilling.

3.2.2 The establishment of the control back pressure model

The calculation formula of bottom hole pressure is in the normal circulation of closed underbalanced drilling:

$$P_{bh} = P_g + P_f + P_a \tag{5}$$

When the formation gas penetrates into the wellbore, in order to maintain the bottom hole pressure in a constant range, the ground pressure can be adjusted to adjust the pressure to compensate for the wellbore pressure fluctuations, then the formula becomes:

$$P_{bh} = P_g' + P_f' + P_a' \tag{6}$$

From the above formula available:

$$P_a' = P_{bh} - P_g' - P_f' \tag{7}$$

Where P_{bh} represents bottom hole pressure, P_g , P_g' respectively represent Hydrostatic column pressure before and after gas invasion. P_f , P_f' respectively represent Cyclic pressure loss before and after gas invasion. P_a , P_a' respectively represent Wellhead back pressure before and after gas invasion.

$P_g{}', P_f{}'$ can be used to seal the underbalanced drilling process multiphase flow analysis model to calculate, so as to establish the formula 7 as shown in the process of drilling under the control of underbalanced drilling.

3.2.3 The solution of control back pressure

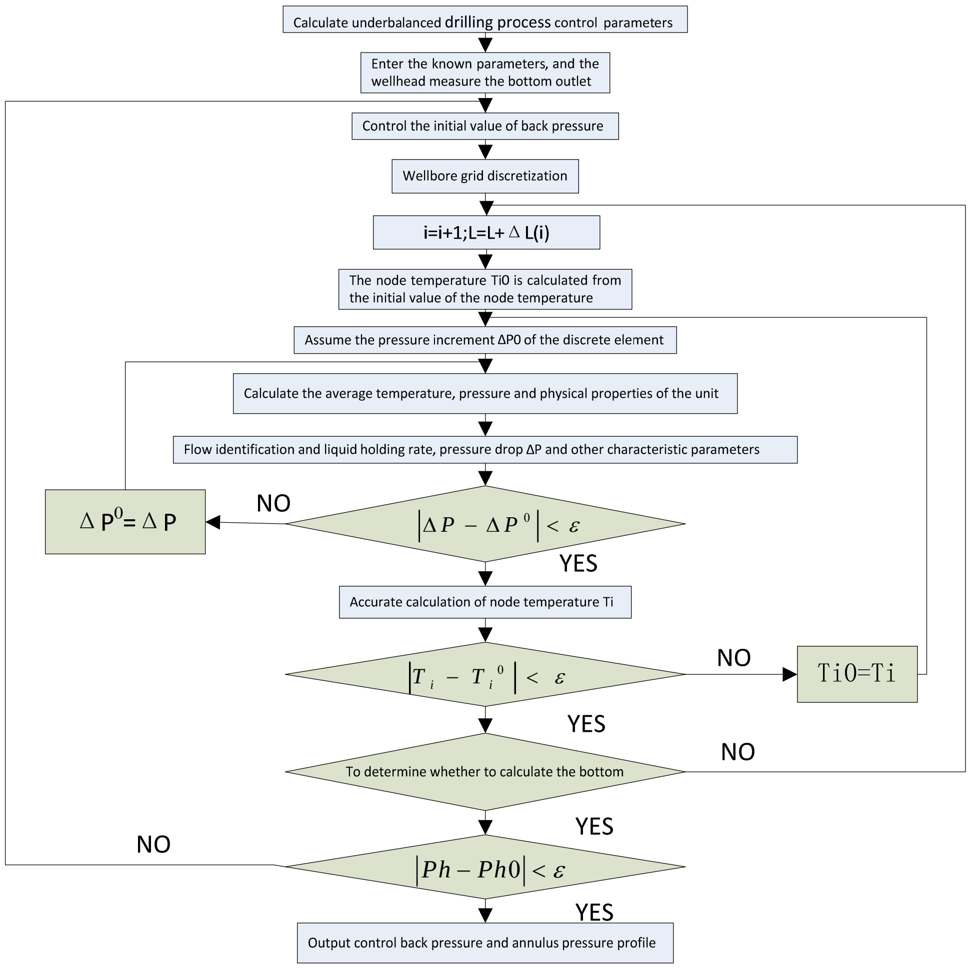

Figure 4 Flow chart of the dynamic analysis of the process of pressure control in airtight underbalanced drilling

Figure 4 is a calculation flow chart for calculating the control back pressure required for closed underbalanced drilling. The solution is as follows:

① The wellhead is taken as the starting point, and the shaft is discretized according to the well depth. The inner loop is mainly responsible for the calculation of the pressure drop of each node, and the outer loop is mainly responsible for the temperature calculation. The beginning of the calculation of the input shaft structure, BHA and hole trajectory data, drilling fluid density, viscosity and displacement, the invading gas in the ground under the environment of density, viscosity and air volume, wellhead temperature, temperature gradient, wellbore inside and outside the wall roughness, et al ,and given the initial control back pressure value.

② According to the gradient of the ground temperature, calculate the temperature increase of the discrete element and the node temperature Ti0;

③ the voltage drop of the discrete element is assumed to be ΔP0, and then calculate the average temperature of the unit and the average pressure;

④ The critical temperature, critical pressure, viscosity, compression factor, density, apparent velocity, liquid viscosity, density, flow velocity, gas - liquid surface tension and so on can be calculated under the conditions of average temperature and pressure.

⑤ Through the multiphase flow analysis model, the characteristics of flow identification and gas-liquid two-phase flow can be calculated.

⑥ to calculate the discrete unit voltage drop and the assumption that the accuracy of the pressure drop to determine whether to meet the requirements, if the requirements of the next step on the calculation, or jump back to step ③ to re-calculate;

⑦ we can be based on the energy equation of the wellbore and heat transfer equation to calculate the discrete element node temperature;

⑧ on the calculated discrete cell temperature and the accuracy of the temperature to determine the accuracy of the temperature to see if it meets the requirements, if not satisfied to jump to the second step to re-calculation, if the accuracy to meet the requirements to enter the next step;

⑨ increase the step size, so that can be calculated to the bottom of the location, if calculated by the bottom of the pressure and a given bottom hole pressure to meet the accuracy requirements, will control the pressure back pressure and annulus pressure profile output, If it is not satisfied, in the first step will control the pressure back to change, and then recalculate.

4. FIELD APPLICATION

Based on the study of bottom hole pressure control principle and wellhead backpressure control method, a closed and underbalanced real-time dynamic control analysis system is developed. The system of closed-load real-time dynamic control analysis system is analyzed and applied in China xx field.

In XX date, the well began to use the closed underbalanced drilling process at a depth of 5581 m, and the drill was drilled to a depth of 5690 m and a total length of 109 m and an average machining speed of 4.25 m / h. In this section of the application of the system for field application testing and analysis.

When the drilling section is normally drilled, the drilling fluid density is 1.2g / cm³ and the displacement is 16L / s. The strata is predicted to have a formation pressure of 61.78MPa (vertical depth of 5338m). In order to realize the underbalanced drilling, maintain the pore pressure below 0.2 ~ 1MPa, maintaining the bottom hole pressure 60.78 ~ 61.58MPa, keep the underbalanced state.

When drilling to 5646m, the real-time monitoring interface of the data set shows that the wellhead back pressure is 1MPa, the pressure, outlet flow, outlet density, export conductance and gas measurement are fluctuating, and the pressure and conductivity are increased and the density value decreased, the observed flame height increased from 2m to 5.9m. At this point, we can determine the bottom of the air volume increases. The monitoring results are shown in Figure 5.

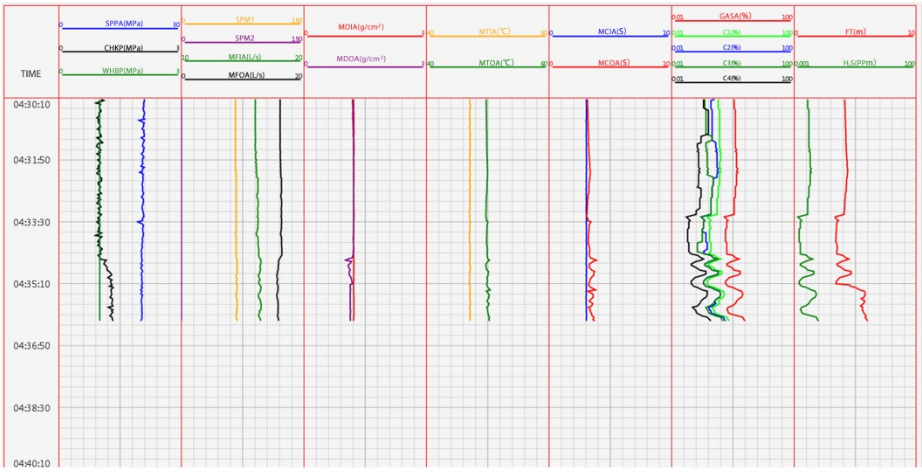

Figure 5 Real - time monitoring of file data

Based on the real - time dynamic analysis of the bottom hole pressure, the dynamic calculation results of the bottom hole pressure are 60.30199MPa when the current well depth is 5646.37m and the outlet gas is 0.35 m³ / s. When the air volume increases, in order to ensure the stability of the bottom hole pressure, wellhead back pressure is controlled and analyzed. Control the bottom hole pressure of 61.5, undervoltage value of 0.23.

According to the results of dynamic control analysis, the data monitoring interface shows that the formation airflow is reduced and the height of the observed flame is reduced after the wellhead pressure command is issued. Therefore, the wellhead back pressure control can quickly adjust the bottom hole pressure to ensure the stability of the wellbore pressure. As shown in Figure 6.

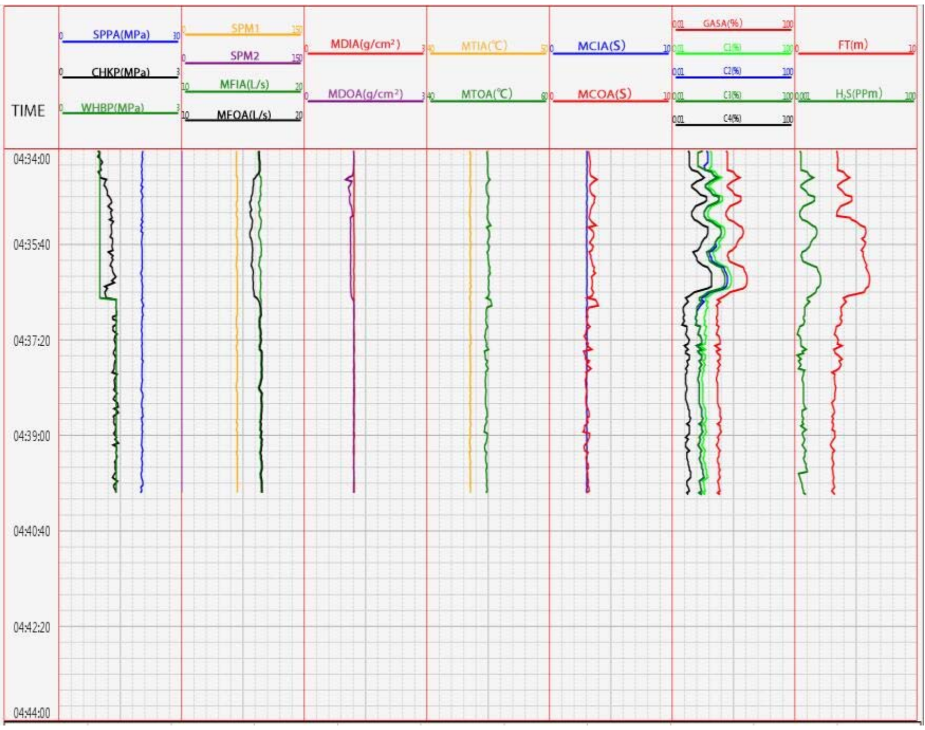

Figure 6 Wellhead back pressure dynamic control result monitoring chart

5. CONCLUSION

In this paper, based on the dynamic control model of well underbalanced wellhead back pressure, and through the study of wellbore pressure relation and wellbore pressure control principle, a set of remote real-time dynamic control analysis technique based on ground measurement is developed. The results show that the system is in good condition and can realize the remote safety real-time monitoring of the wellsite H_2S and the remote real-time monitoring of the bottom hole pressure in the well underbalanced drilling process, which reduces the drilling risk and cost.

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