

Research on Integrated Layer Determination and Fault Crossing Technology of Multi-branch Horizontal Wells for Surface Area Management

Shaopeng Song^{1,*}

¹ School of Safety Science and Engineering, Henan Polytechnic University, Jiaozuo, CO 80523, China

* Corresponding author: ShaoPeng Song (Email: 445135812@qq.com)

Abstract: Based on the application of multi-branch horizontal well technology in surface area management, combined with the hydrogeological structure of the coal bed floor, the method of determining the layer by azimuthal gamma, rock chip logging and drilling parameters is proposed. Combined with the change of azimuthal gamma, determine whether drilling encounters faults or not, put forward the technology of crossing faults when drilling encounters different types of faults, improve the rate of drilling smooth layer, reduce the leakage of drilling fluids, and form a set of key technologies of comprehensive stratigraphy judgment and crossing faults applicable to the grouting of multi-branch horizontal wells at the surface, based on the existing engineering examples, analyze the stratigraphy, tectonic conditions, and the application of comprehensive stratigraphy judgment and crossing faults technology in the case of directional drilling. The average smooth layer rate of Z1 and Z2 hole group is 96.96% and 99.2% respectively, which effectively ensures the quality of grouting in the fault structure area and is of great significance to the prevention and control of water damage in the mine.

Keywords: Ground grouting; Multi-branch horizontal wells Corresponding authors; Azimuthal gamma; Trajectory control.

1. Introduction

With the further development of coal mining, the hydrogeological conditions of the coalfields have become more complicated, and most of the coal mining is threatened by water damage [1-2]. Grouting management is the main technical means for the prevention and control of pressurized water in the coal seam bottom plate [3]. With the development of drilling technology and the wide application of surface multi-branch wells in the field of CBM [4-6]. Surface area treatment has also gradually become the mainstream of coal mine floor water treatment due to its advantages of relatively low treatment cost and low environmental pollution [7-10]. However, due to the complex geology, it also brings a lot of problems, especially the problem of horizontal wells with multiple branches, and how to adjust the drilling attitude in time to ensure that the drilling rate is smooth when encountering the structure. In recent years, many scholars have conducted research. Chen Gang [11] and others selected a more suitable method for field application to the drilling logging system by applying neural network autonomous learning predictive analysis. Hao Dengfeng [12] and others combined directional drilling and geosteering techniques and successfully applied them to the multi-branched horizontal wells in the ultra-advanced grouting renovation project. Dong Shuning [13-14] and others have constructed a theoretical framework and technical system for over-advanced regional management of water damage in coal bed floor.

When surface multi-branch horizontal wells use thin layer tuff as the target layer for grouting and reforming, due to the thinness of the target layer, multi-branch horizontal wells have difficulties in following the layer when drilling, and the drilling fluid leakage is serious when drilling encounters faults. Therefore, to address the above problems, we propose a comprehensive layer judgment for multi-branch horizontal wells when drilling and a fault crossing technology when

drilling a fault in the target layer. By utilizing the gamma value of azimuthal gamma, rock chip logging and various parameters during drilling, it is possible to make a comprehensive analysis to judge the layer and improve the rate of drilling smooth layer; when drilling encountering faults, it is possible to judge the type of faults through the sequence of changes in the upper and lower gamma values, and combined with the previous stratigraphy, it is possible to put forward the key technology of drilling over faults, which will provide the theoretical and technological support for the on-site application.

2. Key Technology for Layer Determination in Surface Multi-Branch Horizontal Wells

2.1. Azimuthal Gamma Judgment Layer

The microprocessor for azimuthal gamma uses the real-time measurement data from the borehole attitude measurement unit to solve for the position of the window centerline, and determines from which direction the measured gamma data comes from by comparing the position of the window centerline with the set position, thus realizing the up and down gamma measurement. Gamma amplitude variations reflect the lithology of the drilled formation, while the sequence of upper and lower gamma variations indicates the location of the top or bottom plate and the interface.

The lithologies indicated by different gamma value ranges are shown in Table 1:

Table 1. Three Scheme comparing

Gamma range	>80API	40-80API	20-40API	<20API
lithology	mudstone	muddy sandstone	siltstone	limestone

2.2. Rock chip logging for stratigraphy

Observe the appearance, shape, color and other physical properties of the rock chips to make a preliminary judgment, if the shape of the multi-angled or flaky, usually is the new drilling of the strata of the rock chips, soft mudstone is often spherical grains, muddy cemented loose sandstone in the form of beans. The main composition of the formation can be initially determined by simple chemical tests. The main component of graywacke is carbonate rock, and the formation can be initially judged by whether or not it reacts with dilute hydrochloric acid; graywacke reacts with dilute hydrochloric acid, and mudstone does not react with dilute hydrochloric acid. Sandstone is mainly composed of sand grains cemented together, of which the content of sand grains is more than 50%, the vast majority of sandstone is composed of quartz or feldspar, quartz and feldspar are the most common components that make up the earth's crust.

When drilling through the layer, you can judge from the increase or decrease of the percentage content of a certain lithology in the rock chips to enter the stratum of what lithology, for the less content of the rock chips can not be ignored, need to carry out a comprehensive analysis, pay attention to whether there is a sign of out of the layer, or whether the drilling encountered faults and other structures, the need to timely adjustment of the drilling attitude until the rock chips are all the rock chips of the layer of the purpose of the grouting transformation, to ensure that the rate of the drilling of the smooth layer.

If there is a new component of rock debris and it increases gradually in the future, it is a sign of the emergence of a new stratum in the well. If the number of new rock chips is small and discontinuous, and disappears after a period of time, it may be that the drilling encounters a hidden structure or a small fault. If the number of new rock chips keeps increasing, or keeps a certain number of rock chips without decreasing or disappearing, it indicates that the drilling hole is being or has been out of the layer, and it should be recorded in time, and combined with the gamma curve to adjust the drilling attitude and find the target layer.

By recording and analyzing the rock chips during drilling and comparing them with those of the previous exploration holes, we can initially judge whether the drill hole is in the target layer or not. During the drilling process, a packet of rock chips is retrieved at 1m intervals to keep samples, and the characteristics of the chips are recorded, which will be convenient for the next drilling to make comparisons.

2.3. Drilling parameter judgment layer

In the drilling process, one drilling time point is recorded every 1m from the bedrock, and data such as drilling depth, drilling time, drilling speed, drilling pressure, sample retrieval time, sample number, etc. are recorded. According to different drilling speeds and pressures, it is easy to judge the lithology of the formation, and the drilling time per unit length of the formation can be used to recognize the change of lithology. Generally speaking, among the common rock strata in the coal bed floor, mudstone has low hardness, sandstone has medium hardness, and graystone has the highest hardness; therefore, the drilling time per unit length is short for mudstone, second for sandstone, and longest for graystone.

During the drilling process, record in detail the original amount of drilling fluid, the remaining amount, the shift

consumption, and the water output of the wellbore at different well depths. Under normal circumstances, the drilling fluid consumption is recorded once every 2h of drilling; the drilling fluid consumption is recorded once every 1h after entering the target layer; if the phenomena of flushing fluid leakage, drilling loss or buried drilling are found, the depth, layer and flushing fluid consumption should be recorded in detail; if any abnormality is found, such as serious leakage of drilling fluid, which is very likely to be the result of drilling encountering faults or other passages, etc., it is necessary to comprehensively analyze whether or not to stop drilling and start grouting at once.

Record the length of each drill pipe from the drill bit, cumulative length, drill pipe type and other parameters, according to the length of the drill pipe to determine the drilling distance, combined with the drilling gamma can be synthesized to determine the three-dimensional coordinates of the drill bit when drilling, according to the hydrogeological conditions explored in the previous exploration holes can be carried out to predict the stratigraphic prediction, so as to facilitate the preparation in advance to meet the tectonic drilling.

3. Key Technology for Surface Multi-branch Horizontal Wells through Faults

If the drill bit encounters a fault after entering the gray rock aquifer, the spatial location of the fault zone encountered by the drill bit can be deduced through the fault characteristics and logging data, combined with the change characteristics of the gamma logging curve, so as to provide reference for the geosteering drilling work. The author will analyze the faults according to the difference between the upper and lower plates, and the difference between the positive and negative faults. When the fault break distance is large, and the break distance is much larger than the thickness of the target layer, the target layer on both sides of the fault is completely staggered, and the target layer suddenly disappears during drilling, it is impossible to directly judge the relative position of the drill bit and the target layer. The method of searching for the marker layer is adopted, based on the geological data and the information of neighboring wells, and combining with the changing characteristics of the gamma logging curve to determine the vertical depth difference with the target layer, and then return to the appropriate position to side drill into the target layer after the marker layer is detected.

3.1. Drilling to positive fault

When drilling meets the positive fault and enters from the lower plate of the fault, through the process of exploring the top, reduce the well inclination angle to make the borehole trajectory downward, through the sandstones and mudstones into the gray rock aquifer, as shown in Fig. 1; the characteristics of the change of the gamma logging curve at this stage: the LWD gamma sensor enters into the sandstone layer first, the low side of the GR firstly increases, the high side of the GR increases with a lag, and maintains a more stable GR value within the sandstone layer, the trajectory The trajectory enters the mudstone layer, the low-side GR increases first, the high-side GR increases with a lag, and maintains a relatively stable GR value in the mudstone layer; as the trajectory extends, it begins to penetrate out of the mudstone into the tuff, and the gamma sensor's low-side

position first touches the tuff, the low-side GR begins to drop rapidly, the high-side GR remains unchanged, and the average GR value begins to show a downward trend, with an increasing amplitude, and the subsequent drop of the low-side GR to a certain value, the high-side GR decreases, and the low-side GR decreases, and the high-side GR decreases. Then the low-side GR decreases to a certain value, the high-side GR decreases, the amplitude gradually decreases and finally the high and low-side GR values tend to be the same.

When entering from the upper plate of the fault, through the process of bottoming, increase the well inclination angle to make the borehole trajectory upward, through the sandstone and mudstone to enter the gray rock aquifer, as shown in Fig. 2; the characteristics of the change of the gamma log curve in this stage are opposite to that of the change of the change of the lower plate.

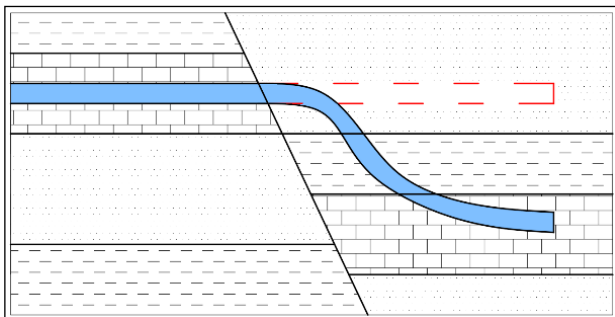


Figure 1. Lower plate of the normal fault

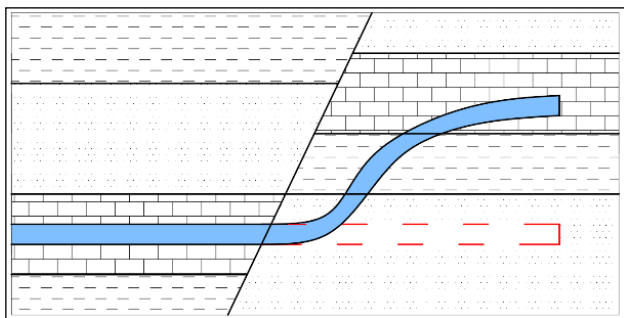


Figure 2. Upper plate of the normal fault

3.2. Drilling to reverse fault

If the drilling encounters the reverse fault, and enters from the lower plate of the fault, through the process of bottoming, increase the well inclination angle to make the borehole trajectory upward, through the sandstone and mudstone into the gray rock aquifer, as shown in Fig.3, the characteristics of the change of the gamma logging curve at this stage: the LWD gamma sensor enters into the sandstone layer, the high side of the GR firstly increases, the low side of the GR increases lagging behind, and maintains a more stable GR value within the sandstone layer; trajectory The trajectory goes upward into the mudstone layer, the high side GR increases first, the low side GR increases with a lag, and maintains a relatively stable GR value in the mudstone layer; as the trajectory extends, it begins to penetrate out of the mudstone into the tuff, and the high side of the gamma sensor contacts the tuff first, the high side GR begins to decrease rapidly, the low side GR remains unchanged, and the average GR value begins to show a decreasing trend with an increasing amplitude, and the high side GR then decreases to a certain value, the low side GR then decreases, and the low side GR then decreases, and the high side GR then decreases, and the low side GR then

decreases to a certain value. Then the GR of the high side decreases to a certain value, the GR of the low side decreases, and the amplitude decreases gradually, and finally the GR of the high and low sides converge to the same value.

When entering from the upper plate of the fault, through the process of exploring the top, reduce the well inclination angle to make the borehole trajectory downward, through the sandstone and mudstone to enter the gray rock aquifer, as shown in Fig. 4, and the characteristics of changes in the gamma logging curve at this stage are opposite to those of the entry from the lower plate.

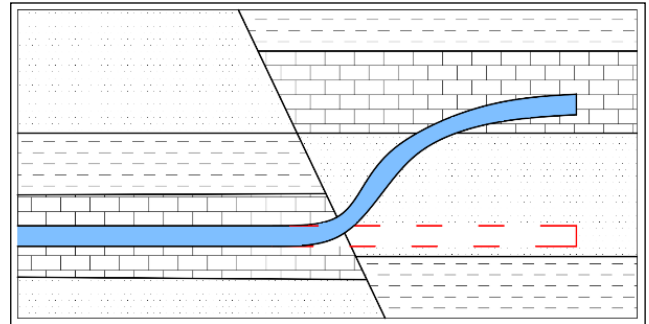


Figure 3. Lower plate of the reverse fault

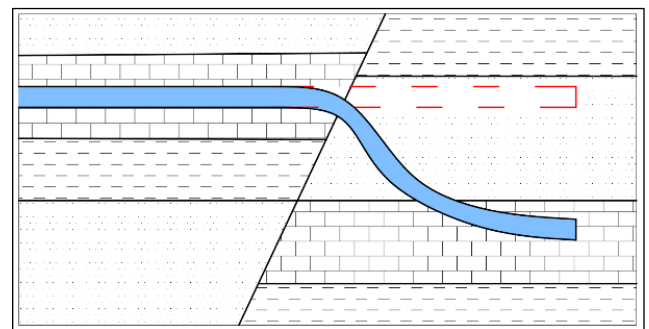


Figure 4. Upper plate of the reverse fault

4. Field Applications

4.1. Application of the combined factor judgment layer technique

Through the change of gamma value, timely response to the drilling trajectory whether out of layer, and make corresponding measures, drilling in the normal working condition of the gamma value is stable at about 20API, it can be deduced that at this time the drilling hole is drilling in the grey layer in the layer, if the gamma value suddenly becomes large, we need to analyze the reasons in a timely manner, combined with the rock chip logging and other drilling time logging information for a comprehensive analysis of the judgment of the layer.

When recording the rock chips, 1 packet was taken at 2~4m in the well section of non-destination layer, and 1 packet was taken at 1m in the well section of destination layer. We also organize the rock chips on the spot, drop dilute hydrochloric acid for verification, record the layer thickness of the rock chips in detail, summarize the rock chip logging table, and file and save the organized rock chip samples to make preliminary judgment and division of the stratigraphy. Take part of the data of construction borehole Z1-6 with depth of 816m-945m as an example, see Table 2.

Table 2. Three Scheme comparing

Cumulative depth(m)	layer thickness(m)	Rock name	Rock chip description
816	36	limestone	Dark gray limestone, color is more homogeneous, the quality is more pure, hard, high content of mud, meet the reaction of dilute hydrochloric acid
847	31	Limestone	Light gray limestone, color uniform, pure, hard, low mud content, meet dilute hydrochloric acid reaction
868	21	Limestone	Gray limestone, color is more uniform, pure, hard, low mud content, meet dilute hydrochloric acid reaction
901	33	Limestone	Light gray limestone, color uniform, pure, hard, low mud content, meet dilute hydrochloric acid reaction
921	20	Limestone	Gray limestone, color is more uniform, the quality is more pure, hard, high content of mud, meet the reaction of dilute hydrochloric acid
945	24	Limestone	Light gray limestone, color is more uniform, pure, hard, low mud content, meet dilute hydrochloric acid reaction

4.2. Application of key technology for drilling through faults

Hole Z1-7 enters the DXF37 fault (H=6.62m) at a depth of 1064m, and there is no leakage in the branch hole when drilling through this section. Due to the large drop of the fault, the drilling encounters the top of the fault and penetrates through the mudstone, and the directional azimuth and inclination angle of the drilling are adjusted in time to quickly enter the target layer of the lower plate of the fault, and this section is the drilling anomaly area. Take drill hole Z1-7 over DXF37 fault as an example, when drilling the DXF37 fault through the bottoming process, increase the well inclination angle to make the borehole trajectory upward, through the mudstone into the gray rock aquifer as shown in Fig.5, the gamma logging curve change characteristics: the LWD gamma sensor enters into the mudstone layer, the high side of the GR first increased, the low side of the GR increase lag, and in the mudstone layer to maintain a more stable GR value; With the extension of the trajectory, it began to penetrate out of the mudstone into the tuff, the high side of the gamma sensor first contacted the tuff, the high side GR began to decline rapidly, the low side GR remained unchanged, the average GR value began to show a downward trend, the amplitude increased, and then the high side GR fell to a certain value, the low side GR followed by a decline in the amplitude of the gradual decrease in the final high and low sides of the GR value tends to be the same as shown in Fig.6.

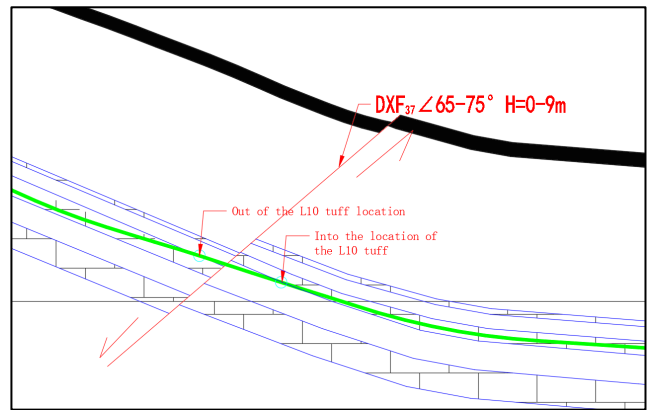


Figure 5. Schematic diagram of drilling through the fault

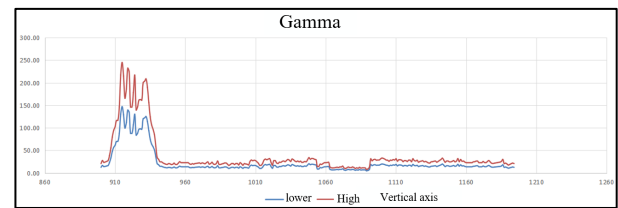


Figure 6. Gamma curve changes when encountering faults

4.3. Engineering application effect

Two groups of holes were completed in the mine, among which one main hole and 10 branch holes were completed in the Z1 group, with an average smooth layer rate of 96.96%, and one main hole and 12 branch holes were completed in the Z2 group, with an average smooth layer rate of 99.2%.

Through the practical application in the mine, the ground multi-branch horizontal well integrated layer judgment and fault crossing technology has achieved very good results and greatly improved the drilling rate of smooth layer.

5. Conclusion

A multivariate stratigraphic method based on azimuthal gamma, rock chip logging and drilling time logging is proposed. The advantages of azimuthal gamma over traditional gamma are explained, and the changes of gamma value in different formations are analyzed; the physicochemical properties of rock chips are summarized to analyze the possible outbursts of layers with different rock chip contents and the emergence of new compositions; and the analysis of drilling time logs, simple hydrological observation, drilling distance and other logging information is used to assist in the stratigraphy determination.

Analyze the change of gamma value of up and down when drilling encountered different types of faults and after adjusting the trajectory according to the different faults of positive and negative and up and down plates. By listing various faults, the type of faults can be inverted through the change of gamma value, so as to adjust the trajectory of drilling in time and reduce ineffective drilling.

By applying the technology of comprehensive stratigraphy and faults in the mine, the rate of drilling smooth layer has been greatly improved, and the quality of grouting in the area of fault structure has been effectively ensured, which will provide useful reference for the management of the area of thin-layered tuff in multi-branch horizontal wells on the ground in the future.

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