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Study on the Layout Form of Comprehensive Mining Working Face with Existing and Abandoned Natural Gas Wells in Coal Mines

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Abstract: The safety issues caused by the phenomenon of overlapping mining in China's mineral resource overlap areas are becoming increasingly prominent. Taking the example of the Shen 30 well (natural gas drilling) within the 5-20111 working face of the Qinglongsi Coal Mine, a study was conducted on the effects of the relative positions of the working face and natural gas drilling on the advancement of the working face. This study is of significant importance for the safe exploitation of overlapping mineral resources. Utilizing the advantages of numerical simulation, numerical models with different relative positions of natural gas drilling and the working face were established to investigate the effects of natural gas drilling at different locations on the displacement and deformation patterns of the working face's roof and the impact on the drilling and floor during the advancement of the working face. The results indicate: (1): As the drilling moves away from the central position of the working face, the high roof displacement area gradually disappears, with the minimum deformation of the roof occurring when the natural gas drilling is located in the middle left position of the working face. (2): Within a range of 80m below the working face floor, the rock within a 0.3m range around the drilling will undergo damage. When the working face moves 14m away from the drilling, both the sealing material inside the drilling and the surrounding rock will undergo yielding damage in the roof.(3): The maximum working resistance of the hydraulic support in the working face is approximately 43.8MPa, with a periodic advance spacing of about 10m to 15m, an average periodic advance spacing of about 12m. When the working face is close to and slightly away from the Shen 30 well, the average periodic advance spacing increases slightly to 14m, and the working resistance of the hydraulic support also reaches a maximum of 43.8MPa. As the working face continues to advance, the average periodic advance spacing returns to around 12m.

Keywords: Cross Mining; Numerical Simulation; Ground Pressure Manifestation; Roof Deformation.

1. Introduction

With the rapid growth of the Chinese economy, the nation's demand for energy continues to rise, leading to an increasing focus from enterprises on the exploration and development of mineral resources [1]. Consequently, the phenomenon of overlapping mineral resource extraction areas has emerged, bringing to light increasingly significant safety concerns[2].

In recent years, overlapping mining rights have become a focal point of research, primarily focusing on theories, policies, and the status of mining rights overlap[3]. Consequently, research on the production safety of coal and natural gas cross-mining has been progressively growing year by year[4]. Yuan Liang[5] presented an overview of the key technological systems and current developments in the integrated extraction of coalbed methane both above and below ground and the simultaneous extraction of coal and gas in China. Wang Jinguo[6] used the Hechaogou coal mine as a case study to outline the detection methods for abandoned oil and gas wells within coal mine fields. Li Hui[7] conducted a risk analysis on incidents of toxic and harmful gas poisoning and asphyxiation related to abandoned oil and gas wells during mining operations at a certain coal mine workface. Yang Shengli[8] and others presented the technological pathways and research directions for safe, environmentally friendly, and efficient coal and natural gas extraction in China. Huang Huazhou[9] studied methods for improving the performance of surface wells in remote coalbed methane depressurization by altering well locations within mining areas. Addis[10] analyzed the impact of petroleum extraction on reservoir horizontal stress patterns and investigated how stress reduction affects drilling stability. Whittles[11] and colleagues utilized FLAC software to examine how borehole casings deform into an "S" shape under rock shear forces and simultaneously assessed the influence of rock types on borehole stability.

In practical engineering, coal mining and natural gas drilling, although belonging to different fields, can sometimes encounter cross impacts and conflicts. Therefore, when coal mining intersects with natural gas drilling, it is essential to conduct rational coordination and planning to minimize the effects between the two operations. Additionally, comprehensive risk assessment and control are necessary to establish scientific management measures, ensuring the smooth progress and safe operation of coal mining activities.

2. Arrangement of the Influence of Working Face Advancement on Drillings

The 5-20111 working face of the Qinglongsi Coal Mine is located in the 5-201 block in the southwest part of the field. It primarily extracts coal from the 5^{-2} seam. Within the working face, there are PK67 boreholes and the Shen 30 well (a natural gas drilling well). In the vicinity, there are the 10-7 boreholes and 4-5 boreholes. The ground elevation ranges from 1080m to 1190m, while the bottom elevation of the 5^{-2} coal seam is between +1003m and +1010m.

The location of the Shen 30 well remains unchanged. By altering the layout of the working face, the relative positions of the working face and the drilling well are modified to study the impact of natural gas drilling wells on mining operations when located at different positions relative to the working face. To improve computational efficiency and post-processing, the model is constructed as half of the entire working face, specifically the left portion.

In the model, five working conditions are established, as shown in Figure 1, corresponding to natural gas drilling wells numbered 1 to 5. Well No. 1 is located at the center of the working face, while Well No. 5 is positioned at the far left of the working face near the return airway. Each natural gas drilling well is spaced 10 meters apart. Well No. 1 is located at Y = 5 meters in the model, Well No. 2 at Y = 15 meters, and Wells No. 3 to No. 5 follow this pattern accordingly.

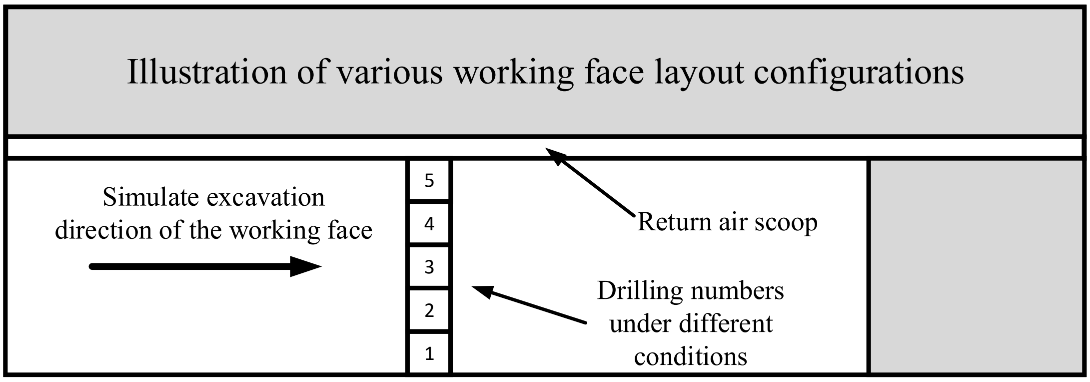


Figure 1. Schematic Diagram of the Model with Different Relative Positions of Drilling and Working Face

3. The Influence of Different Working Face Layouts on Roof Stability

3.1. The Influence of Positional Changes on Roof Displacement

Different scenarios are set up to observe the vertical displacement of the roof when the relative positions of the drilling and working faces change. As the coal seam is extracted, the overlying strata above the goaf will progressively collapse as the working face advances, leading to periodic vertical displacement zones due to cyclic loading effects.From the mine pressure display cloud map in Figure 2, it is evident that the maximum working resistance of the hydraulic supports is mainly concentrated in the middle area of the working face, with clear periodic loading intervals. Therefore, a cross-section in the middle area of the working face is selected for studying the impact of changes in the position of the natural gas drilling on the vertical displacement of the roof.

As the working face advances, the roof displacement exhibits periodic fluctuations with an average interval of 18 to 21 meters. At the location where the working face passes over the natural gas drilling, the vertical displacement of the roof reaches 2.26 meters, and the 2.26-meter displacement zone is adjacent to the natural gas drilling location. From Figure 2(a) to Figure 2(e), it can be observed that as the natural gas drilling moves away from the center of the working face, the periodic fluctuations in the vertical displacement of the roof remain relatively consistent. However, the high displacement zone in the central area gradually diminishes.

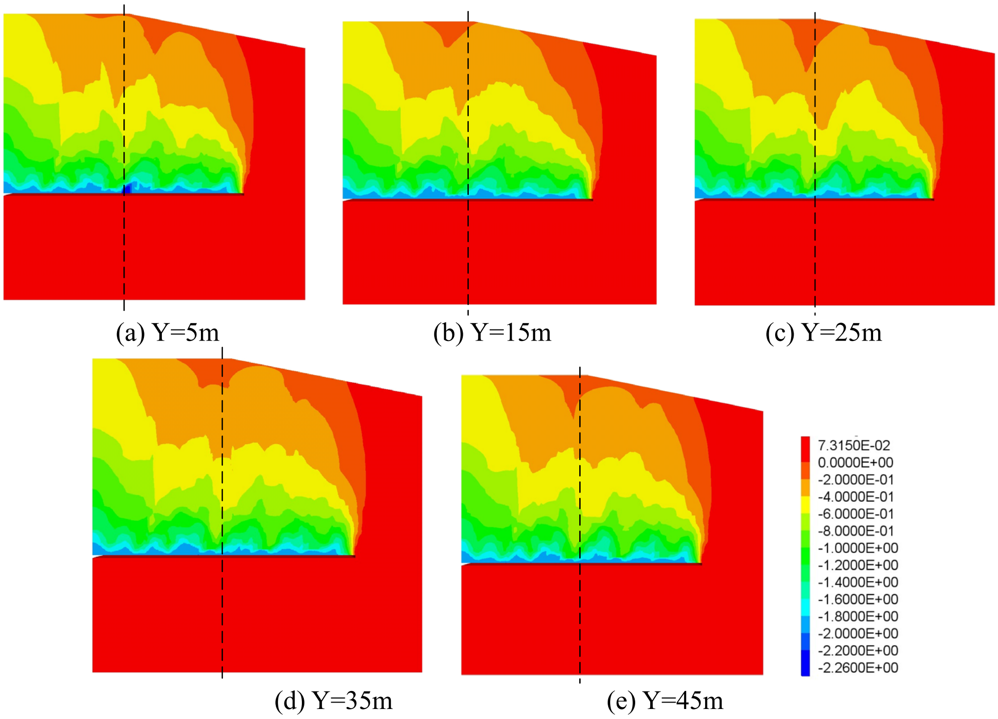
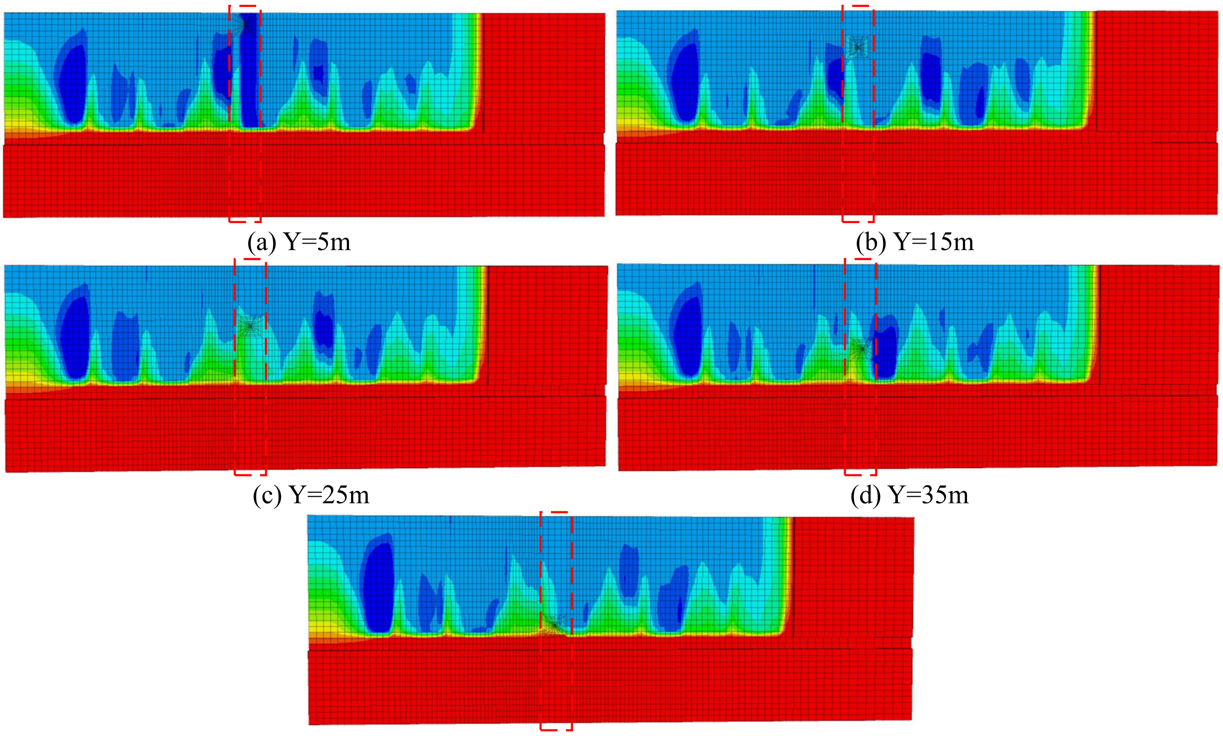


Figure 2. Cloud Map of Vertical Displacement of the Roof with Changes in Relative Positions(MPa)

3.2. The Influence of Positional Changes on Roof Deformation

The cloud map of roof deformation when the relative positions of drilling and working faces change is shown in Figure 3. When the natural gas drilling is located at the center of the working face, Y=5m, the red box area exhibits significant vertical displacement, forming a strip of high displacement zone.From Figure 3(a) to Figure 3(e), it can be observed that as the natural gas drilling moves away from the central area towards the left side of the working face, the strip of high displacement zone gradually disappears. Overall, there is a trend of higher displacement in the middle area and lower displacement towards the left side. When the natural gas drilling is positioned at the far left of the working face, close to the return airway, the influence of the return airway causes a slight increase in displacement within the red box area. Hence, it can be inferred that the roof deformation is minimized when the natural gas drilling is located at the middle left position of the working face.



(a) Y=5m (b) Y=15m (c) Y=25m (d) Y=35m (e) Y=45m

Figure 3. Cloud Map of Roof Deformation with Changes in Relative Positions

In summary, when the working face advances over the natural gas drilling, the maximum vertical displacement of the roof near the drilling reaches 2.26 meters. As the working face continues to progress, the vertical displacement of the roof gradually decreases and stabilizes, with the high displacement zone appearing to the left of the natural gas drilling in a strip-like area. When the natural gas drilling is placed at different positions along the working face, the roof deformation in the strip-like high displacement zone varies. The roof deformation is minimized when the natural gas drilling is positioned at the middle left of the working face, indicating that the roof is most stable as the working face progresses at this point.

4. Manifestation Patterns of Strata Pressure in the Working Face

4.1. Variations in Hydraulic Support Working Resistance During Working Face Advancement

Leveraging the numerical simulation analysis and integrating real mining conditions, the layout of the working face is adjusted. The Shen 30 well is relocated to a position 100m to the left of the working face, closer to the left-middle area. Real-time monitoring of hydraulic support working resistance will be conducted post mining face extraction.

In Figure 4, the graph illustrates the variations in working face resistance of the hydraulic support system during the mining process of the 5-20111 working face, approximately 50 meters before and after the Shen 30 well. As the working face advances, the hydraulic support resistance gradually increases to 43.1 MPa. Subsequently, at intervals of 10-15 meters, the working face hydraulic support resistance fluctuates from troughs to peaks, with a minimum resistance of about 24.9 MPa and a maximum resistance of about 43.8 MPa. By observing the time nodes of the first occurrence of displacement peaks and working resistance in the hydraulic support system, and considering the frequency of resistance fluctuations, it is apparent that the periodic pressing distance of the working face is approximately 10-15 meters, with an average periodic pressing distance of around 12 meters.

4.2. Patterns of Overlying Strata Pressure Manifestation During Working Face Advancement

During the advancement of the working face passing through the Shen 30 well, the manifestation cloud chart of the overlying strata pressure is depicted in Figure 5. The maximum working resistance of the hydraulic support system is predominantly concentrated in the central region, demonstrating clear periodic pressing intervals.Throughout the progression of the working face, the average periodic pressing distance slightly increases to around 14 meters near and around the Shen 30 well, with the hydraulic support system's maximum working resistance peaking at 43.8 MPa. As the working face continues to advance, the average periodic pressing distance returns to approximately 12 meters upon moving away from the Shen 30 well.

Analysis of hydraulic support working resistance and strata pressure cloud map indicates that, in this layout of the mining face, the impact of natural gas drilling on the face advancement is minimal. The strata pressure at the mining face appears normal, meeting safety production requirements.

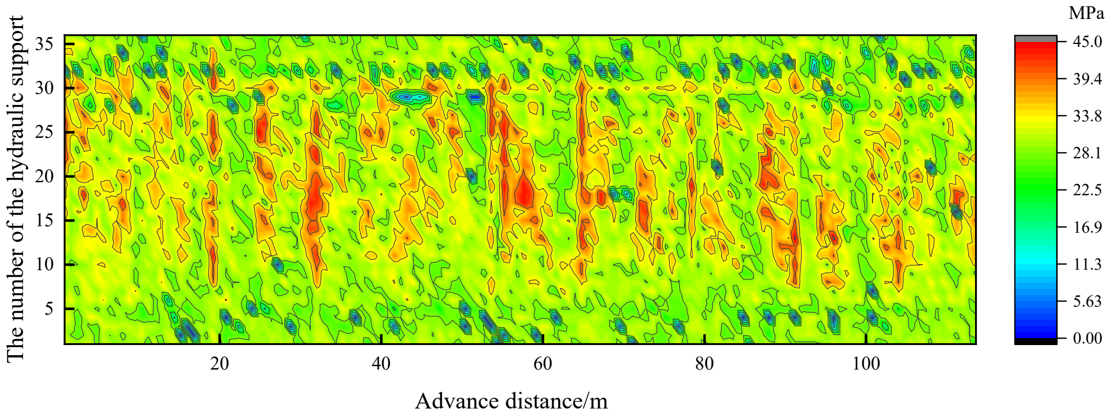


Figure 5. The operating resistance of the hydraulic support is shown in a contour diagram

5. Conclusion

Based on the conditions of the 5^{-2} coal seam, a model was established for natural gas drilling at various positions on the working face to investigate the impact of the working face advancement on the natural gas drilling at different locations on the working face. The key research findings are as follows:

(1) As the central position of the working face moves away from the natural gas drilling site, there is not significant cyclic variation in the vertical displacement of the roof, but the high-displacement zone in the central area gradually diminishes. Regarding roof deformation, there is an overall trend of larger displacements in the central region and smaller displacements on the left side.In general, when the natural gas drilling is located in the middle position on the left side of the working face, the high-displacement zone of the roof is minimized. The roof deformation is minimal when the drilling is positioned in the middle of the left and right sides of the working face. Therefore, the impact of natural gas drilling on the advancement of the working face is minimal when the drilling is located in this position.

(2) As the mining face advances, the maximum working resistance of the hydraulic supports reaches approximately 43.8 MPa. Analysis of the resistance fluctuations indicates that the periodic advance distance of the mining face ranges from 10m to 15m, with an average of about 12m. Near the "Shen 30" well, the average periodic advance distance increases slightly to 14m, with the hydraulic support's maximum working resistance also peaking at 43.8 MPa. As the mining face progresses, the average periodic advance distance returns to around 12m after moving away from the "Shen 30" well. The strata pressure at the mining face appears normal, meeting safety production standards.

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