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Managing Surface Cracks and Pillar Stress Concentration in Shallow Multi-Seam Mining

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Abstract

In order to ensure safe mining and reduce surface damage in shallow multi-seam mining, the failure characteristics of interburden strata with different coal pillars offset distances between pillars in the upper and lower seams, the distribution characteristics of stress concentration in coal pillars, and the development characteristics of stratum cracks and subsidence were investigated by physical and UDEC2D simulation [1-15]. Meanwhile, the effect of different coal pillar offset distances on stress concentration of coal pillar and development of stratum cracks were studied. Based on those results, a formula for safe mining and reducing surface damage was established, which provided a theoretical basis for safe and environmentally friendly mining in shallow multi-seam. According to the results, the optimal coal pillar offset distance (the side to side horizontal distance of the upper and lower coal pillars) between the upper and lower coal seams was developed to reduce the stress concentration of coal pillars and surface damage. The results of this study have been applied in Ningtiaota coal mine and have achieved good results in safe and environmentally friendly mining.

Introduction

Physical and UDEC2D simulations were used to investigate the failure characteristics of interburden strata with different coal pillars offset distances between pillars in the upper and lower seams, the distribution characteristics of stress concentration in coal pillars, and the development characteristics of stratum cracks and subsidence in shallow multi-seam mining.

Meanwhile, the impact of various coal pillars offset distances on coal pillar stress concentration and stratum fracture formation was investigated. Based on these findings, a formula for safe mining and reducing surface damage was developed, providing a theoretical foundation for safe and environmentally friendly shallow multi-seam mining. The best coal pillar offset distance (the side to side horizontal distance between the upper and lower coal pillars) between the upper and lower coal seams was created based on the findings to limit coal pillar stress concentration and surface damage. The findings of this study were implemented in the Ningtiaota coal mine, yielding positive outcomes in terms of safe and environmentally friendly mining.

Subjective Heading

For a long time, Chinese scholars have made great achievements in the single shallow seam mining. However, research on the shallow multiple-seam mining is in its infancy in China. studied the abutment pressure of coal pillars on the floor, and proposed a method to determine the optimal location of entry by using the rate of stress change Zhang et al. studied the depth of floor failure after mining extremely close upper coal seam, and proposed an optimum pillar offset distance 7.5 m between upper and lower seam when the interburden thickness was 9 m

The Jurassic Coalfield in northern Shaanxi is one of the seven largest coalfields in the world, of which 60% of the reserves belong to the shallow multi-seam mining. There are two main problems in shallow multi-seams mining. One is the stress concentration of coal pillars in the upper coal seam that causes the strong weighting and affects the lower coal face safe mining and another is that the surface cracks formed by shallow multi-seam mining seriously damage the surface environment Therefore, achieving a safe, environmentally friendly and sustainable mining of coal is an important subject in future mining

Discussion

Zhou used the Lame-Maxwell Equation to derive analytic solutions for the plane wedge and semi-plane subjected to stress concentration Huang et al. simulated the crack height of multi-seam mining in Wanli Coal Mine by UDEC2D Yao et al. simulated the development of overburden cracks under repeated mining Li et al. studied the overburden movement and cracks development in multi-seam pressure relief mining Yu studied the roof structure of multi-seam and its influence on the lower coal seam mining . Huang et al. established two models of coal pillar offset distance determination, one to avoid the stress concentration of lower seam pillar, and the other to decrease the uneven Through physical simulation, studied the stress-fracture of surrounding rock in closely-spaced multi-seam mining. established the floor stress calculation model to determine the damage zone of floor . suggested that the reasonable coal pillar width of high-gas coal seams mining should be optimized by considering the coal pillar stability, the pressure relief effect and the coal recovery rate discussed the surface movement and subsidence with different thicknesses of soil layer in high-intensive coal mining . studied the evolution characteristics of overburden and surface cracks, and found that the surface cracks alone the coal pillar boundary are the main cracks need to be controlled in shallow multi-seam mining However, there are few studies that have looked at both the impact to mine safety and surface protection in shallow multi-seam mining.

When the coal pillars were overlapped or the offset distance of pillars was less than 0 m (the offset distance of pillar center line between

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the upper and lower seam was 0–20 m) The out by area of the panel in the lower coal seam was completely in the superimposed stress zone of the upper and lower seam coal pillars. The maximum stress was at the center of the coal pillar. The abutment pressure reached 8 m wide in the horizontal direction and the stress was maintained above 20 MPa. As a result, it is difficult to control the surrounding rock of the roadway in the lower coal seam panel and rib spalling is easy to happen.

With the increase in offset distance, the vertical stress of pillar in the lower coal seam decreases gradually. When the offset distance of pillars was 20 m, the stress concentration zones of coal pillar were hardly When the offset distance of pillars was 40 m, the stress of 2-2 coal seam pillar decreases obviously, and the caving strata on the left side of 1-2 coal seam pillar were compacted Meanwhile, the width of pillar stress greater than 20 MPa was about 3 m, and the stress distribution on the coal pillar was basically uniform. When the offset distance reached 50 m, the lower coal pillar was in the compacted area of the upper coal seam mining, and the vertical stress of the lower coal pillar increased slightly, but the increase was not significant.

With the increase of coal pillar offset distance, the peak vertical stress of coal pillar in the lower coal seam reduced first and then increased, and there existed an optimum interval. When the pillars were in the overlapped layout, the peak stress of the lower coal seam is the largest. With the increase of pillar offset distance, the peak stress of the lower coal seam pillar reduced continuously. When the pillar offset distance between the center of pillars was 40 m, the peak stress of the lower coal seam pillar was the smallest. When the offset distance between pillars was more than 50 m, the lower pillars were in the compacted area of the goaf of the upper coal seam, and the peak stress began to rise again.

The vertical stress distribution of coal pillars with different offset distances in 2-2 coal seam is shown in , and the maximum stress variation characteristics is consistent with the physical simulation

Based on the mining condition of shallow multi-seam in Ningtiaota Coal Mine, through physical and numerical simulations, as well as measured surface cracks data, this paper studied the stress concentration of coal pillars with different coal pillar offset distances and the development characteristics of stratum cracks. The research results can provide scientific basis for environmentally friendly mining in shallow multi-seam.

Overburden caving characteristics and pillar stress distribution

The characteristics of overburden caving and pillar stress distribution are carried out on the same model due to the high cost and extended time of physical simulation experiment. The experimental process begins with the mining of the top coal seam's left working face, which has a width of 245 meters. The right working face of the higher coal seam, with a width of 245 m, is mined after the coal pillar with a width of 20 m is reserved. The lower coal seam is mined after the overburden caving is stable.

According to the physical and numerical simulations, an environmentally friendly and safe mining can be realized by adopting an optimal coal pillar offset distance, by making the coal pillar of lower coal seam located in the stress-relaxation zone Eq. of the upper seam mining, and at the same time, taking into account the uniform surface subsidence Eq. So, the equation for coal pillar offset distance for safe and environmentally friendly mining is L is the optimal coal pillar offset distance between the upper and lower coal seams, m.

According to the geological conditions of Ningtiaota Coal Mine, coal seam inclination is about 1°. At present, the coal mine mainly mines the 1-2 seam (upper seam) and 2-2 seam (lower seam). The average thickness of 1-2 coal seam is 2.0 m, 2-2 coal seam is 5.0 m, and the average thickness of interburden strata between the two seams is 33 m. The pillar width of lower seam is 20 m. The roadway width is 5 m. According to the physical simulation results, the stress transfer angles $\phi 1$ is 40° and $\phi 2$ is 70°. The average rotation angle of the upper and lower coal seam roof is 10°. Substituting those parameters into the calculation.In conclusion, the optimal coal pillar offset distance for safe mining and reducing surface damage is 40–66 m, which is consistent with the physical simulation results. The results of this study were tested in Ningtiaota Coal Mine, which has obtained good effect in environmentally friendly mining.

During the mining process of shallow multiple-seam, with the increase of the coal pillar offset distance in the upper and lower coal seams, the vertical stress of the coal pillar in the lower coal seam section is firstly decrease and then increase, and there is a stress-relaxation zone. The surface boundary cracks caused by the section coal pillars are the main cracks on the surface, and the surface cracks can be reduced or closed by an optimal coal pillar offset distance.

The stress concentration of coal pillars and surface cracks are related to non-uniform subsidence. By selecting an optimal offset distance of the upper and lower coal pillars, the non-uniform subsidence of the coal pillar support zone can be decreased to reduce pillar stress concentration and surface damage. There is a coupling control effect for safe and environmentally friendly mining.

The equation calculation formula for safe mining and reducing surface damage was established, which provided a theoretical basis for safe and environmentally friendly mining in shallow multi-seams. Combined with the panel geological conditions in Ningtiaota Coal Mine, it is concluded that the optimal coal pillar offset distance of 1-2 and 2-2 coal seams is 40–66 m. Furthermore, the application in Ningtiaota Coal Mine has achieved a good effect and realized safe and environmentally friendly.

Overburden cracks

Overburden cracks after mining include bed separations and upward cracks. Separation cracks in the goaf far from the working face were gradually closed due to non-uniform overburden bending. At a 50° angle, upward cracks occur along the boundary around the working face.

Surface cracks

The peak vertical stress of the coal pillar in the lower coal seam decreased initially, then climbed, and there was an optimum interval as the coal pillar offset distance increased. The lower coal seam has the highest peak stress when the pillars are in the overlapping configuration. The peak tension of the lower coal seam pillar gradually decreased as the pillar offset distance increased. The peak stress of the lower coal seam pillar was the smallest when the pillar offset distance between the center of pillars was 40 m. The lower pillars were in the compacted area of the goaf of the upper coal seam when the offset distance between pillars was more than 50 m, and the peak stress began.

Coal pillar offset distance for reducing surface damage

Different coal pillar offset distances have a substantial effect on the regularity of surface sinking, according to physical simulation.

In the 1-2 and 2-2 coal seams, the surface subsidence curves for the overlapping configuration and 40 m offset distance (side-to-side layout) of pillars are illustrated in. Subsidence above the coal pillar was the smallest in the surface subsidence basin (the center section of the curve) when the coal pillar was overlapped, generating a W-shaped surface subsidence curve. Surface subsidence in the middle of the basin tended to be flat as coal pillar offset distance increased. In the middle section of the basin, differential surface subsidence decreases when the offset distance of the coal pillar is 40 m.

Due to the high cost and long period of physical simulation experiment, the characteristics of overburden caving and pillar stress distribution are carried out on the same model. The experimental process is, firstly, that the left working face of the upper coal seam is mined, with a width of 245 m. After the coal pillar with a width of 20 m is reserved, then the right working face of the upper coal seam is mined, with a width of 245 m. After the overburden caving is stable, the lower coal seam is mined. The working face of the lower coal seam is excavated to the right (lower pillar is a moving face to simulate the different side-to-side distances with upper pillar of 1-2 coal seam), and the overburden caving characteristics and pillar stress distribution with different offset distances between the left coal pillar of lower seam and the right boundary of the coal pillar in upper coal seam is mainly observed.

Conclusion

During the shallow multiple-seam mining operation, when the distance between the coal pillars in the higher and lower coal seams grows, the vertical stress of the coal pillar in the lower coal seam section decreases at first, then increases, forming a stress-relaxation zone. The major fractures on the surface are surface boundary cracks created by section coal pillars, and the surface cracks can be reduced or closed by an appropriate coal pillar offset distance.

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Conflict of Interest

The authors declare that they are no conflict of interest.

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