Study on the Influence of Layout of Double Coal Seam Working Face on Overlying Strata

Xueyang Sun¹,², Qi Zhang¹,²,*, Cheng Li³ and Lei Zhang¹

¹Xi’an University of Science and Technology, Xi’an, China
²Shaanxi Provincial Key Laboratory of Geological Support for Coal Green Exploitation, Xi’an, China
³Key Laboratory of Mine Geological Hazards Mechanism and Control, Xi’an, China

*Corresponding author

Abstract. The design of mining face is very important, it is not only an basis for rational and effective coal mining, but also affects the subsidence area and surface environment of overlying strata. Taking a coal mine as an example, study the development law of coal mining subsidence under the condition of double coal seam mining by means of the combination of similar material simulation experiment and numerical simulation. The results obtained by the two methods are basically the same. The larger the width of the coal pillar, the smaller the overlapping area of the upper and lower coal seam, and the smaller the influence range of coal seam mining deformation and failure. It is suggested that the mining time and mining distance of the two coal seams should be extended, the width of coal pillar should be increased, so as to slow down the deformation and damage range of overburden, and protect the surface ecological environment.

Keywords: Double seam mining; Coal mining subsidence; Simulation of similar materials; Numerical simulation.

1. Introduction

Subsidence disaster is one of the problems restricting the development of mining areas¹. Scientifically predicting the occurrence of mining subsidence disaster and its characteristic parameters is important for protecting the ecological environment and geological environment of mining areas. For multi-seam mining in mine field, due to complex and diverse mining methods and superimposed and staggered working face layout in different coal seams, the subsidence characteristics are significantly different from that of single-seam mining². The characteristics of overburden movement and deformation caused by multi-seam mining are special³. At present, the prediction accuracy of mining subsidence is relatively low. In double seam mining, the domestic scholars in the structure of overburden rock and the rules of overburden rock fracture have carried out a lot of research, puts forward the repeated mining goaf roof above the mining height are broken when the increase will lead to cause signs of renewed activity⁴,⁵, and under the dual pressure relief mining effect, some strata crack extending, compaction, has experienced the generation, tension, and complex process, such as compaction theory⁶, and build the repetition of overburden rock under mining fissure elliptic cast belt form the dynamic mathematical model of⁷. There are few studies on the subsidence characteristics of multi-seam mining at present, and the research degree is relatively low, and the prediction accuracy of mining subsidence needs to be improved.

Take a mine in Shaanxi province as an example, By using the method of similar material simulation experiment and numerical simulation, study the influence of different layout on mining subsidence and
the variation rule of subsidence parameters, in order to provide technical support for the coal mining subsidence disaster assessment.

2. Simulation Experiment of Similar Material in Double Coal Seam Mining

2.1. Experimental Scheme Design

2.1.1. Summary of Mine. The mine is located in the secondary tectonic unit of Ordos basin. The geological structure is simple, the tectonic morphology is monoclinal structure. The main recoverable coal seam is no.3 coal, the thickness is 4.85m ~11.90m, the average thickness is 8.36m.

2.1.2. Determination of Test Conditions. In the experiment, the 30101 working face and overlying strata were selected as the simulation prototype. The geometric similarity ratio of the model is 1:250. The density similarity ratio is 1:1.6. The steel frame structure was adopted in the experiment, the model size was 200cm×200cm×20cm. Fine sand is used as aggregate, gypsum as cement and large white powder as filler. White mica is used to simulate the bedding surface between strata. The thickness of the model and its rock mechanics parameters are determined according to the actual situation of the mine.

2.2. Experimental Process and Analysis

2.2.1. Experimental Rack Installation. The experiment established model 1 with a width of 20m and model 2 with a width of 40m respectively. In the two model coal seams, three working faces are set up, two upper coal and one lower coal. The working face length is 40cm. Coal pillars of 10m are reserved on each side of the model. Eight rows of measuring points were arranged in both models, with one row is set in the middle of the two coals and one row of measuring points is set in every 10cm above the upper coal seam. The excavation is 5cm each time (Figure. 1).

2.2.2. Experimental Process and Analysis. In the experiment, the advance of working face is accompanied by the collapse of overburden of coal seam. The height and length of overburden collapse increase with the advance of working face. The first cave-in time of different working faces is different. The first cave-in time of the first and second working faces of upper coal in the model 1 experiment appears respectively when the working face pushes 25cm and 30cm, the lower coal face pushes 20cm, and the first cave-in time of the working face pushes 30cm (Figure.2). In the model 2 experiment, the first collapse of the top of the first and second upper coal face appeared when the working face advanced 30cm, the lower coal face advanced 30cm, and the first collapse of the top of the working face appeared when the lower coal face advanced 35cm (Figure.3). When the coal working face in the lower coal seam of model 1 is pushed up to 60cm, full mining is achieved. The caving height is 10.5cm, and the calculated caving zone height is 26.25m. The maximum height of the fracture zone is 24.5cm, and the actual height is calculated to be 61.25m. When the lower coal face in the second coal seam of the model is pushed up to 58cm, full mining is achieved and the caving height is 9.8cm. The calculated caving zone height is 24.5m. The maximum height of the fracture zone is 21.3cm, and the calculated height is 53.25m.
Due to the different width of coal pillars and their superposition relation between the working faces, the upper coal has different influence on the lower coal seam. The first coal separation and the first collapse occurred earlier in the lower coal of model 1 than model 2, and the collapse height also decreased. Comparing the results of the model mining process is shown in table 1.

2.2.3. Analysis of Overburden Subsidence Law. Figure 4 is the surface subsidence curve obtained by the experiment. Under the influence of coal pillar, the subsidence of different strata of overburden is slowed down. The surface subsidence curves of both models show wave-like characteristics on the whole. The maximum subsidence value of model 1 is 2.5m, and the maximum subsidence value of model 2 is 2.25m. The change trend of the two is basically the same, but the change of model 1 is larger and more obvious.
Table 1. Comparison table of model mining process.

| the main parameters | model 1    | model 2    |
|---------------------|------------|------------|
| Coal pillar         | 20cm       | 40cm       |
| fracture            | 8          | 5          |
| max fracture hight  | 24.5cm     | 21.3cm     |
| Rock separation     | 6          | 4          |
| max separation length | 30cm     | 16cm       |
| Initial collapse position | 25cm   | 30cm       |
| upper coal 1st working face | 30cm   | 30cm       |
| lower coal working face | 30cm   | 35cm       |
| Max collapse height | 8.5cm      | 8cm        |
| upper coal 2nd working face | 10cm   | 9.2cm      |
| lower coal working face | 10.5cm | 9.8cm      |

Figure 4. Surface subsidence curve of model.

3. Numerical Simulation of Double Coal Seam Mining

3.1. Model Establishment

According to the working face layout, 100m is reserved along the strike to protect the coal pillar, 10m is reserved along the trend to protect the coal pillar, and the width of the coal pillar is 20m between the working face in model 1. In model 2, the width of coal pillar between working faces is set as 40m.

3.2. Model Parameters

The thickness of rock strata used in the numerical simulation of a mine in northern Shaanxi is consistent with the thickness of rock strata used in the simulation of similar materials. According to the actual situation of the mine, the mechanical parameters of strata were used in the simulation.

3.3. Comparative Analysis of Simulation Process and Simulation Results

3.3.1. Change Process and Analysis of Overburden Subsidence. In the process of advancing the working face, the subsidence of overburden of coal seam increases continuously. In terms of the subsidence range, the influence range of model 2 is reduced compared with model 1, but the decrease is not obvious. With regard to the width of coal pillar left behind, the two models push forward the working face with different width of coal pillar left behind. When the two models push forward to the front of reserved coal pillar, the subsidence amount of the two models is almost the same. However, as the working face continues to advance, the subsidence curve under different width of coal pillar left behind and different pressure difference starts to show obvious differences. With the advance of the working face, the subsidence value of overlying strata on the coal seam increases in different degrees.
However, the subsidence value increment of overlying strata is relatively small when the coal pillars on the left and right sides and around the middle are left.

3.3.2. Principal Stress Analysis. During the mining process of upper and lower coal seams, stress changes occur in the overlying strata on the working surface (Figure 5). By observing the stress changes of each strata, it can be seen that the distribution form of the maximum principal stress in the overlying strata of coal seams during the advancing process of the working face corresponds to the deformation generated during the experimental excavation of similar materials. In the process of upper coal mining, the maximum principal stress zone mainly appears at the top of coal seam. The main stress zone of strata above the goaf presents an "arc" shape with low on both sides and high in the middle, with tensile stress as the main stress. Due to the action of tensile stress, the overlying strata on the working surface began to collapse and the mining subsidence phenomenon began to appear. When the top coal mining, the maximum principal stress in overburden above goaf is distributed symmetrically. With the mining of the lower coal, the tensile stress at the center of the bottom plate decreases, and the stress distribution on both sides of the top of the goaf is high and the middle is low.

![Figure 5 Maximum principal stress nephogram](image)

3.3.3. Analysis of Plastic Zone Simulation Results. As shown in Figure 6 (a), the distribution of the plastic zone in the overlying strata is different when the working face is at different advance distances. When the upper coal is mined, the top plate above the goaf in model 1 appears shear failure first, but the plastic zone failure degree is not high and the shear failure is not obvious. With the advance of the lower coal mining face, tensile failure occurs at both ends of the goaf while shear failure occurs. When the lower coal mining is completed, both shear failure and tensile failure over the lower coal goaf are obviously developed.

When the working face with a pillar of 40m coal is advancing, the distribution of the plastic zone in the overlying strata is shown in Figure 6 (b). When the upper coal is mined, the top plate above the goaf of the model also appears shear failure, but the shear failure range is changed, which shows that the shear failure range generated along the y direction becomes larger, while the shear failure range along the z direction decreases. In the process of advancing the lower coal mining face, tensile failure still occurs at the edge of both ends of the goaf, and the form and extent of failure are basically consistent with model 1. With the increase of the width of the remaining coal pillar, model 2 shows a trend of slowing down the subsidence and reducing the damage degree of each stress. By comparing the shape of the plastic zone after completion of mining and combining with the maximum principal stress cloud map after completion of model excavation, the height of model 1 caving zone is 29.7m and the height of fracture zone is 65.5m. The collapse zone height of model 2 is 28.6m, and the fracture zone height is 55.25m. By combining the numerical simulation model and similar material model, the overall comparison shows that the width of coal pillar set in model 1 and model 2 is 20m and 40m respectively, and the resulting interseam overlap length is 40m and 30m respectively. The larger the width of coal pillar set in double-seam mining, the smaller the pressure difference is, and the smaller the overburden damage degree is when coal mining.
4. Conclusion

Results of Simulation experiment and numerical simulation show that the larger the width of coal pillar left in the working face, the smaller the influence of coal mining on the overlying strata, and the smaller the influence area of overlying strata deformation and damage, and the superposition area of the upper and lower working faces decreases, the subsidence of different strata of overburden slows down, and the weaker the influence on the surface. The numerical simulation results show that the overburden displacement deformation caused by mining is not obvious at the beginning and end of excavation, and it mainly appears in the middle process of working face advance.

Reference

[1] TANG Fuquan, HUANG Han, SUN Xueyang, et al. 2016, The influence of mining subsidence on terrain factors in gully region of loess [J]. Journal of Arid Land Resources and Environment. PP124–128.

[2] SUN Xueyang, YANG Xu, LI Pengqiang, et al. 2016, Influence of Mining on Landslide Disturbance Under the Same Inclination of Coal Measure Strata and Landslide [J]. Safety in Coal Mines. PP36–39.

[3] HAN Guangsheng, CHENG Jianwei, YI Guangwang. 2011, Overview of research and application on prediction technology of foreign mining subsidence [J]. Journal of Safety Science and technology. PP41–45.

[4] PAN Ruikai, CAO Shugang, LI Yong, et al. 2018, Development of overburden fractures for shallow double thick seams mining [J]. Journal of China Coal Society. PP2261-2268.

[5] JIANG Fuxing, YAO Shunli, WEI Quande, et al. 2015, Tremor mechanism and disaster control during repeated mining [J]. Journal of Mining & Safety Engineering. PP349-355.

[6] LI Shugang, DING Yang, AN Zhaoqeng, et al. 2016, Experimental research on the shape and dynamic evolution of repeated mining-induced fractures in short-distance coal seams[J]. Journal of Mining & Safety Engineering. PP904-910.