

# **Influence of Mining and Retaining Parameters on Evolution of Hazard Rockburst in Strip-pillar Mining**

**WANG Chunqiu<sup>1,2</sup>, LI Wenshuai<sup>1,2</sup>, GU Shitan<sup>1,2</sup>, MA Chuanle<sup>1,2</sup>, XIAO Zhimin<sup>1,2</sup>**

(1. State Key Laboratory of Mining Disaster Prevention and Control Co-founded by Shandong Province and the Ministry of Science and Technology, Shandong University of Science and Technology, Qingdao 266590, China; 2. College of Mining and Safety Engineering, Shandong University of Science and Technology, Qingdao 266590, China)

## **Abstract**

Stress concentration caused by deep strip-pillar mining will give rise to rockburst. Mining and retaining parameters have a major influence on stability of coal pillar. Ideally, FLAC3D was used to analyze the distribution and evolution of vertical stress, deformation, advanced abutment pressure and elastic strain energy density under the conditions of different mining and retaining which determined the scope of the dangerous zone ahead the mining face, and basis was provided for rockburst prevention in deep strip-pillar mining.

**Keywords:** mining and retaining parameter; strip-pillar mining; advanced abutment pressure; elastic strain energy

density; hazard of rockburst

## **1. Introduction**

Rockburst is one of the worst natural disasters in the world coal mining. The vast majority of coal mines and rock in China have a strong impact or obvious tendency, and coal rock impact is extremely serious under certain critical depth. With the coal resources gradual depletion in part of the old mining, strip mining which can control the overlying strata and surface subsidence effectively and protect ground building (structure) and ecological environment was widely used to extend the mine length of service in major mines in China. Because of presence of coal pillar, stress abnormal distribution within a certain range of coal pillar and itself caused the occurrence of

rockburst. It was widespread concerned in the domestic and foreign scholars [1-8] because of the occurrence of rockburst and frequent pillar instability in strip-pillar mining.

Mechanical model of coal pillar rockburst was built by Pan Yishan and Zhang Mengtao[3] by cusp catastrophe model and the necessary and sufficient conditions of rockburst occurrence were obtained. In terms of load, strength, stability and size of pillar, the theory and analysis methods of stability of strip pillar were systematically reviewed by Xie Heping[4]. The instability and failure of strip coal pillar along strike which was a typical nonlinear process was proposed by Guo Wenbing[5、6], and the cusp catastrophic model for instability and failure of strip coal pillar along strike by catastrophic theory was established, and the formula of fully essential condition for instability failure of strip coal pillar was derived. Ideally, numerical simulation was used to analyze the distribution and evolution of vertical stress, deformation, advanced abutment pressure and elastic strain energy density under the conditions of different mining and retaining width which determined the scope of the dangerous zone ahead the

mining face provided basis for rock burst prevention in deep strip-pillar mining.

## **2. Numerical analysis model**

Mining and retaining width are the key parameters in deep strip-pillar mining. Generally, the wider of mining width, the stronger rock pressure with large scale behavior of overlying strata. The stress concentration, pressure bumping and the scale affected by abutment pressure will also increase. Conversely, with the mining width decreasing, stress concentration and pressure bumping also decrease. The retaining width that is so large that a big range of original rock stress areas existing up the pillar gives rise to rockburst difficultly. Conversely, the smaller retaining width which makes the lateral sides of the coal pillar bear pressure superposition, leads to rock burst easily.

The FLAC3D software was used to simulate rockburst occurrence in strip-pillar mining. The Mohr-Coulomb yield criterion was used in the process of simulation and the size of model was 400m×150m×100m. In order to eliminate the boundary effect of model, as can be seen from Figure 1, there would be a certain wide pillar in model boundary, and X direction was the face direction and

Y direction was advancing direction. Boundary conditions: the four sides of the model were restricted by horizontal displacement and the bottom was restricted by vertical displacement, and 22.5MPa vertical stress was imposed on the model of the boundaries because of the 1000-meters depth. Physical and mechanical parameters of the rock selected were listed in Table 1.

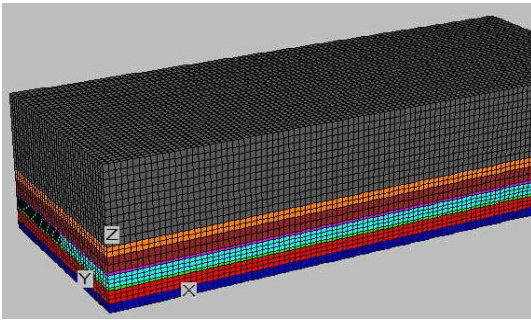


Figure.1 Numerical model mesh

No coal pillar recovery was simulated. In order to simulate the law of distribution

of stress and deformation under different mining and retaining conditions in strip-pillar mining, the simulation suggestion were as follows:

(1) Retaining width fixed

Fixed retaining width 80m and mining width was taken 60m, 80m and 100m.

(2) Mining width fixed

Fixed mining width 80m and retaining width was taken 80m, 60m and 40m.

Excavation sequence: 1# strip was first mined and 2# was second. As can be seen from Figure 2, 2# working face had been advanced to 80m.

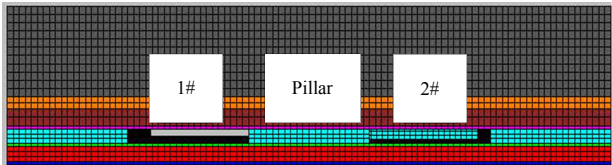


Figure.2 Excavation sequence diagram in strip-pillar mining

Table 1 Physical and mechnaical parameters of coal seam and rock in model

Rock	Lithology	Thickness /m	Bulk density d(kg/m³)	Elastic modulus K/GPa	Shear modulus G/GPa	Angle of internal friction	Cohesion /MPa	Tensile strength /MPa
Roof	Sandstone	55.0	2500	2	1.50	31	8.0	2.00
	Silty sandstone	7.0	2480	1.94	1.11	31	4.5	1.59
	Mid-fine grained sandstone	10.5	2560	1.67	1.00	31	30.2	5.50
Coal seam	Silty sandstone	2.0	2480	1.94	1.11	31	4.5	1.59
	Coal	8.5	1400	1.11	0.54	32	2.0	0.85
	Silty sandstone	2.0	2480	1.94	1.11	31	4.5	1.59
Floor	Mid-fine grained sandstone	9.0	2560	1.67	1.00	31	30.2	5.50
	Fine grained sandstone	6.0	2560	2.44	1.68	27	8.0	3.20

### 3. Influence of mining and retaining parameters on vertical stress and deformation in strip-pillar mining

#### 3.1 Retaining width 80m fixed

Fixed retaining width 80m and mining width respectively was taken 60m, 80m and 100m. When the 2# working face advanced to 80m, measuring line was arranged in strips near the roadway of 2# working face. Stress distribution and deformation were shown in Figure 3 to Figure 5, and positive values represented the front of working face and negative values represented the back of working face.

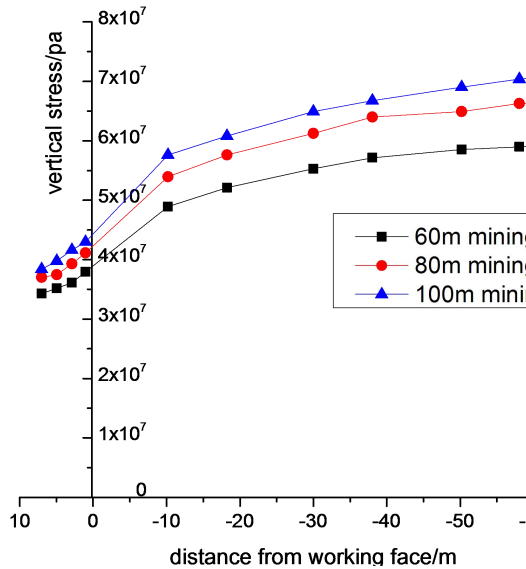


Figure.3 Vertical stress distribution curve of pillar side

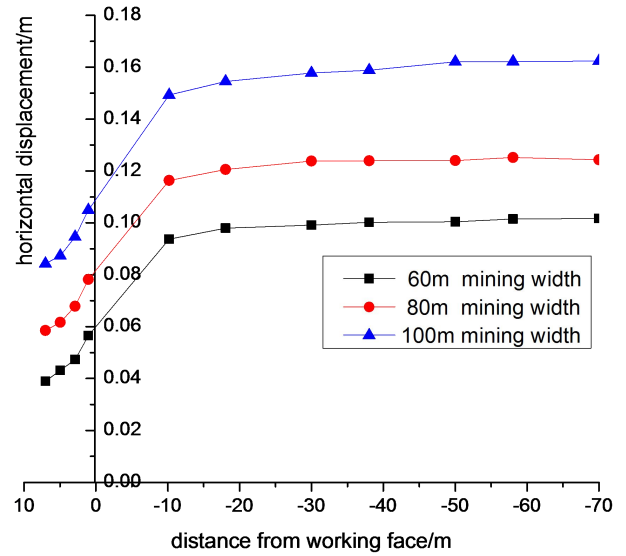


Figure.4 Horizontal displacement distribution curve of pillar side

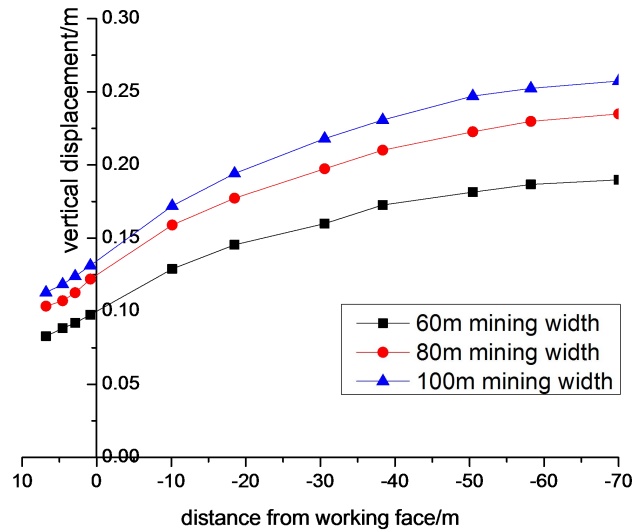


Figure.5 Vertical displacement distribution curve of pillar side

As can be seen from Figure 3 to 5, when the mining width respectively was 60m, 80m, 100m, the stress out of the range of 10m square back of the working face

respectively was 48.9Mpa, 53.4Mpa, 57.8Mpa and stress concentration factors respectively were 2.04, 2.23, 2.41(in-situ stress was 24MPa); horizontal displacement respectively was 0.10m, 0.12m, 0.15m; vertical displacement respectively was 0.13m, 0.16m, 0.18m and the stress and displacement showed an increasing trend away from face. Thus, out of the range of 10m square back of working face, there was a certain impact on the risk of pillar and pressure bumping also increased with the increasing of mining width.

### 3.2 Mining width 80m fixed

Fixed mining width 80m and retaining width respectively was taken 80m, 60m and 40m. When the 2# working face advanced to 80m, measuring line was arranged in strips near the roadway of 2# working face. Stress distribution and deformation were shown in Figure 6 to Figure 8 and postive values represented the front of working face and negative values represented the back of working face.

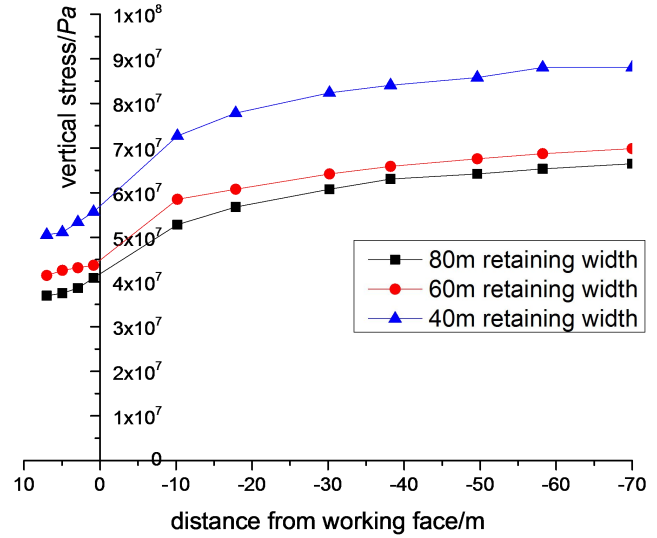


Figure.6 Vertical stress distribution curve of pillar side

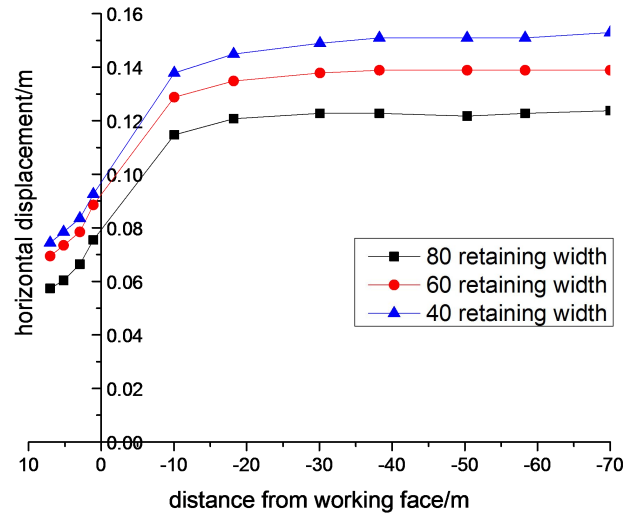


Figure.7 Horizontal displacement distribution curve of pillar side

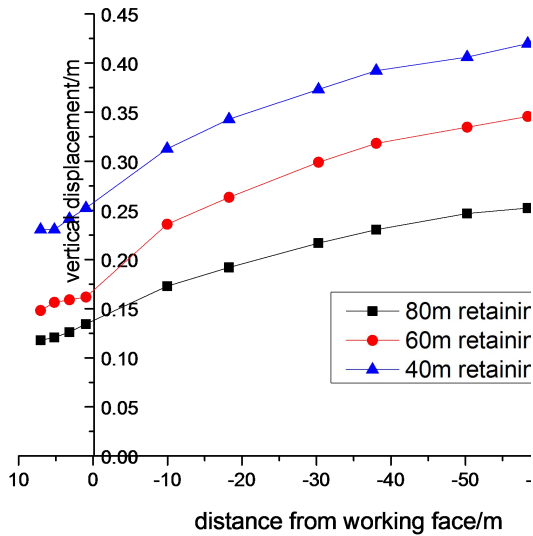


Figure.8 Vertical displacement distribution curve of pillar side

As can be seen from Figure 6 to 8, when the retaining width respectively was 80m, 60m, 40m, the stress out of the range of 10m square back of working face respectively was 53.4Mpa, 58.4Mpa, 72.6Mpa and stress concentration factors respectively were 2.23, 2.43, 3.03(in-situ stress was 24Mpa); horizontal displacement respectively was 0.12m, 0.13m, 0.14m; vertical displacement respectively was 0.18m, 0.23m, 0.31m and the stress and displacement showed an increasing trend away from working face. Thus, out of the range of 10m square back of working face, there was a certain impact on the risk of pillar and pressure bumping also increased with the decrease of retaining width.

#### 4. Influence of mining and retaining parameters on advanced abutment pressure and energy distribution in strip-pillar mining

##### 4.1 Retaining width 80m fixed

When the working face advanced to 80m, monitoring points were arranged in front of 2# working strips and stress distribution and deformation ahead of mining face were shown in Figure 9 to Figure 11.

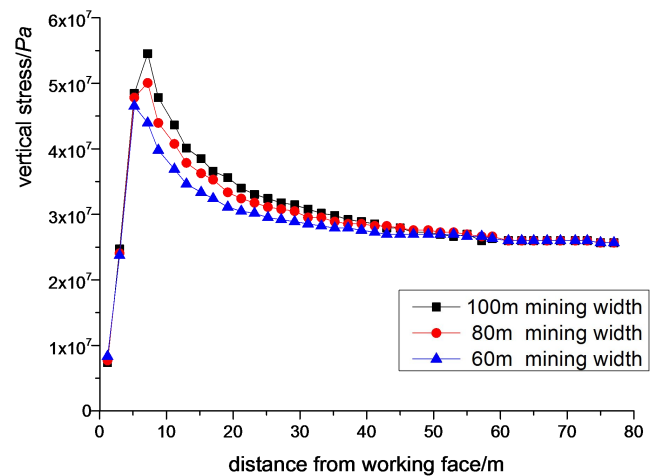


Figure.9 Abutment pressure distribution curve ahead of mining face when advanced to 80m

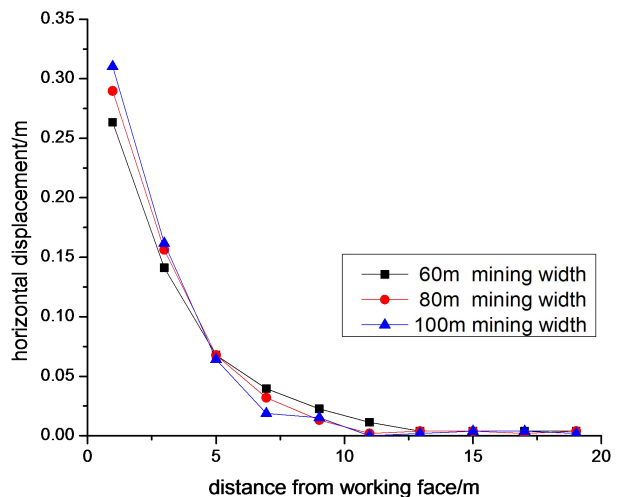


Figure.10 Horizontal displacement distribution curve ahead of mining face when advanced to 80m

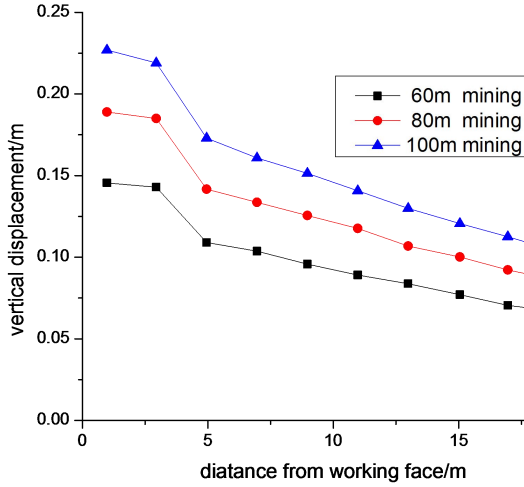
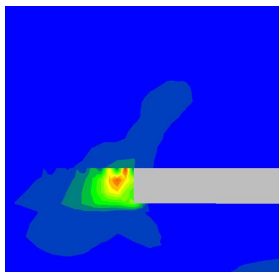


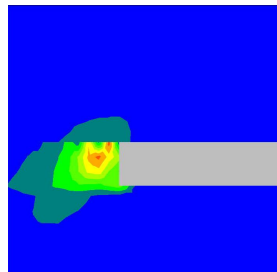
Figure.11 Vertical displacement distribution curve ahead of mining face when advanced to 80m

As can be seen from Figure 9 to 11, when the mining width respectively was 60m, 80m, 100m, stress concentration

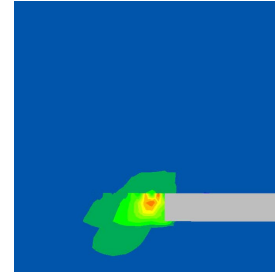
continued to increase ahead of working face with the working face advanced; When the working face advanced to 80m, the peak of advanced abutment pressure reached the maximum and respectively was 47MPa, 50.2MPa, 55.3Mpa and respectively ahead of the working face 5m, 7m, 7m. Stress concentration factors respectively were 1.96, 2.09, 2.3(in-situ stress was 24MPa); horizontal displacement in coal wall respectively was 0.26m, 0.29m, 0.31m, and vertical displacement respectively was 0.14m, 0.19m, 0.23m. With the mining width increasing, the front abutment pressure and displacement increased with greatly increasing risk of rockburst occurrence. When mining width was 100m, the rockburst occurred more easily. The roadway within the range of 7m square ahead of working face was at dangerous area.



(a)Mining width 60m



(b)Mining width 80m



(c)Mining width 100m

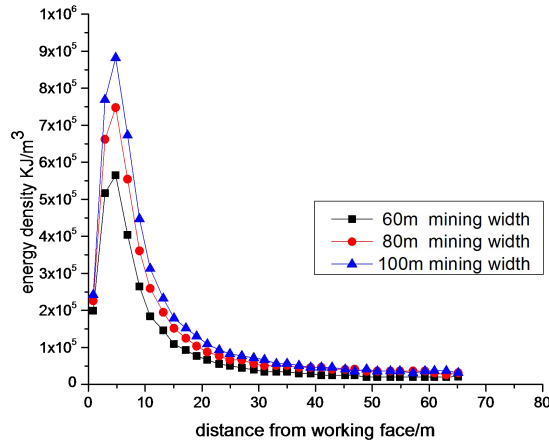


Figure.12 Elastic strain energy density distribution curve ahead of working face(kJ/m³)

Elastic strain energy density distribution in front of working face was shown in Figure 12. The elastic strain energy was mainly in the coal which was more than that of in coal roof and floor. With the increasing distance from working face, elastic strain energy density decreased under the condition of 3 kinds of mining width and reached a peak in front of 5m at working face which respectively was 569kJ/m³, 745kJ/m³, 885kJ/m³ that could be seen from figure 12. Therefore, the roadway within the range of 5m square ahead of working face was at dangerous area with rockburst occurrence in 3 kinds of mining width. When mining width was 100m, the rockburst occurred more easily.

#### 4.2 Mining width 80m fixed

When the working face advanced to 80m, monitoring points were arranged in front of 2# working strips and stress distribution and deformation in front of

mining face were shown in Figure 13 to Figure 15.

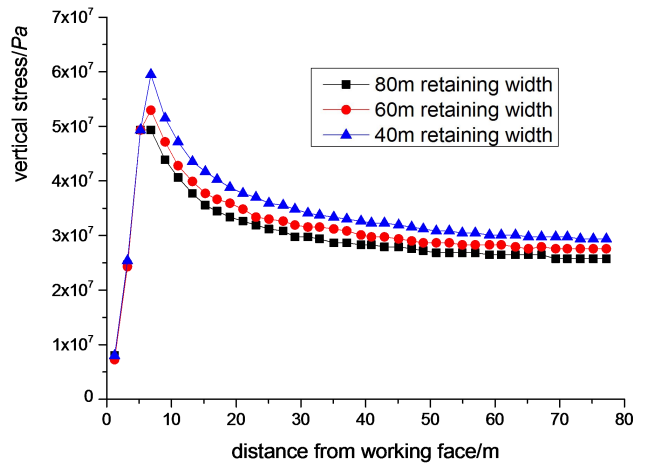


Figure.13 Abutment pressure distribution curve ahead of mining face when advanced to 80m



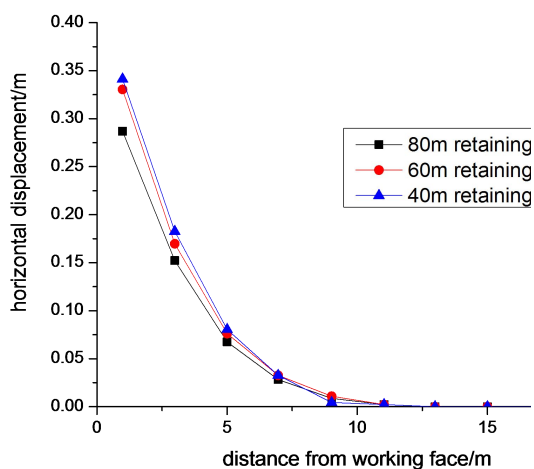


Figure.14 Horizontal displacement distribution curve ahead of mining face when advanced to 80m

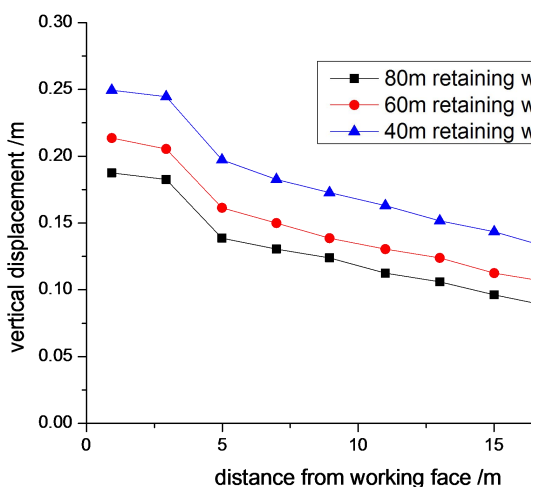
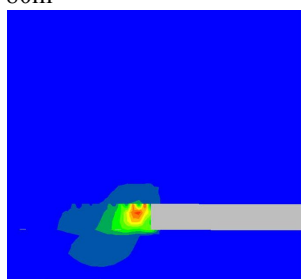
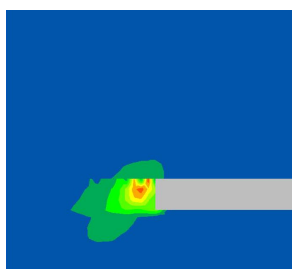


Figure.15 Vertical displacement distribution curve ahead of mining face when advanced to 80m

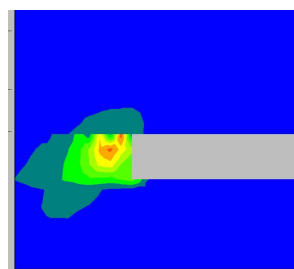
As can be seen from Figure 13 to 15, when retaining width respectively was 80m, 60m, 40m, stress concentration continued to increase ahead of working face with working face advanced; when the working face advanced to 80m, the peak of advanced abutment pressure reached the maximum and respectively was 50.2Mpa, 52.9Mpa, 59.1MPa and ahead of the working face 7m. Stress concentration factors respectively were 2.1, 2.2, 2.46(in-situ stress was 24MPa); horizontal displacement in coal wall respectively was 0.29m, 0.33m, 0.34m, and vertical displacement respectively was 0.19m, 0.21m, 0.25m. With the retaining width decreasing, the front abutment and displacement increased with greatly increased risk of rockburst occurrence when the mining width was fixed. When retaining width was 40m, the rockburst occurred more easily. The roadway within the range of 7m square ahead of working face was at dangerous area.



(a)Retaining width 40m



(b)Retaining width 60m



(c)Retaining width 80m

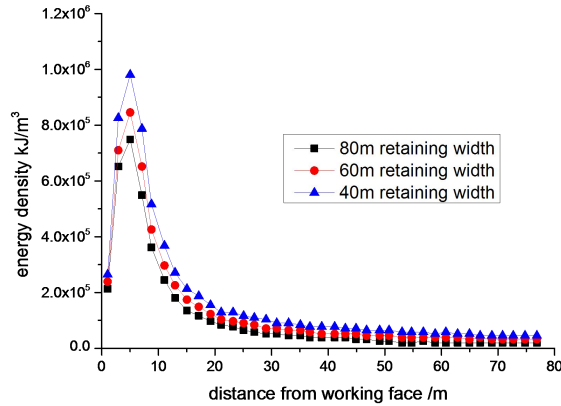


Figure.16 Elastic strain energy density distribution curve ahead of working face(kJ/m<sup>3</sup>)

Elastic strain energy density distribution ahead of working face was shown in Figure 16. With the increasing distance from working face, elastic strain energy density decreased under the conditions of 3 kinds of retaining width and reached a peak in front of 5m at working face which respectively was 745kJ/m<sup>3</sup>, 846kJ/m<sup>3</sup>, 993kJ/m<sup>3</sup> that was could be seen from the figure. Therefore, the roadway within the range of 5m square in front of working face was at dangerous area with rockburst occurrence in 3 kinds of retaining width. When the retaining width was 40m, the rockburst occurred more easily.

## 5. Conclusions

(1) The range of 7m square ahead of 2# working face in roadway and 10m square back of 2# working face were at dangerous area with rock burst occurrence when the retaining or mining width was fixed.

(2) As the mining width was fixed, the advanced abutment pressure and displacement increased with the retaining width deceasing. When the retaining width was 40m, the rock burst was easier to happen.

(3) As the retaining width was fixed, the advanced abutment pressure and displacement increased with the mining width increasing. When the mining width was 100m, the rock burst was easier to happen.

## Acknowledgments

This work is financially supported by National Natural Science Foundation of China (No.51374140; No.51204102).

## 6. References

- [1] WANG Lianguo, MIU Xiexing. Study of mechanism of destabilization of the mine pillar based on a cusp catastrophic model[J]. Journal of Mining & Safety Engineering, 2006, 23(6): 137-140.
- [2] PANG Yue, JI Caihong, LI Aiwu.

Annotation of total potential energy function for dynamic failure of rock[J]. Chinese Journal of Geotechnical Engineering, 2007,29(6): 831-836.

[3] PAN Yishan, ZHANG Mengtao. Analysis of the physical processes of rock burst occurring with Catastrophe Theory[J]. Journal of Fuxin Mining Institute, 1992,11(1):12-18.

[4] XIE Heping, DUAN Fabing, ZHOU Hongwei, etc. Recent developments of theory and analysis methods of strip pillar stability[J]. China Mining, 1998, 7(5): 37-41.

[5] GUO Wenbing, DENG Kazhong, ZOU Youfeng. Cusp catastrophic model of instability of strip coal pillar along strike[J]. Chinese Journal of Rock Mechanics and Engineering, 2004, 23(12): 1996-2000.

[6] GUO Wenbing, DENG Kazhong, ZOU Youfeng. Study on failure and instability of strip coal pillar by catastrophic theory[J]. Journal of China University of Mining & Technology, 2005, 34(1): 77-81.

[7] ZOU Youfeng, CAI Huabin. Research status of strip coal pillar stability and its main problems in China. Journal of Mining & Safety Engineering[J], 2006, 23(2): 141-145.

[8] CHEN Shaojie. Basic experimental study on long-term stability of deep strip coal pillar[D]. Qingdao: Shangdong University of Science and Technology, 2009.