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Stability Analysis on Fault Zone Based on Mining Experiment Reducing of Coal Pillar

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Abstract Based on the field engineering geology and the mechanical properties of rocks of Longdong coal mine, the vertical displacement of coal roof of the two fault walls was tracked and monitored with the reducing of coal pillar by similar material simulation experiment. The results show that, with the reducing of coal pillar width, the displacement of coal roof of the hanging wall goaf was getting larger. The displacement increased with the shortening of the distance form coal roof and the maximum displacement was 4.75m while the displacement of foot wall rock was not obvious. When the coal pillar width was 30m, the displacement of coal roof became mutation meanwhile the vertical displacements between the two sides of fault zone show significant differences. The displacement difference was 0.14m. Obviously, the fault zone became dislocation leading to the instability and activation of fault zone. The research results can provide basis and reference for the reasonable design of fault coal pillar.
Keywords fault zone, coal roof, similar material simulation, fault coal pillar, vertical displacement, water inrush

Introduction

The rock which attracts the most attentions of underground mining is broken meanwhile it's also one of the main reasons causing the deformation of the roadways and water-inrush from coal floor (Tang et al. 2006). According to statistics, above eighty percent of water-inrush accidents of the North China type coal field are related with faults (Peng et al. 2009). There has been a series of similar material simulation tests about the water-inrush mechanism caused by coal mining and the waterproof coal pillar research (Li et al. 1996; Li 1995; Xie et al. 2005; Liao et al. 2008; Cai et al. 2003 Guan et al. 2003; Wang et al. 2006; Gong et al. 2005). The mining activity near fault zone which may lead to the activation of the fault can not be ignored. The fundamental reason of fault activation is due to mining and the disturbed stress field produced different mining effects between the two sides of the fault zone resulting in fault dislocation and activation. In addition, this is one of the main factors for water-inrush (Wu et al. 2007; Li et al. 2002; Li et al. 1996; Feng; Fu 2004; Unve; Yasitli 2006).

The water-inrush accidents can be avoided effectively by setting suitable coal pillar. So, this paper focused on the analysis of displacement characteristics above the coal roof and the critical condition of fault dislocation. The results can provide a basis for the setting of coal pillar.

Research and design of model

The geology of model prototype

The test prototype is Longdong coal mine which is located in the northwest of Xuzhou about 86 km and in south of Peixian about 25 km. Longdong coal mine belongs to the North China type deposited coalfield and the main coal seams contain 7# coal and 21# coal. The 7# coal which belongs to the Permian Shanxi formation was the main coal of this test. The thickness of 7# coal is 5.5 m and the buried depth is 450 m. The direct roof of 7# coal is mudstone and the hanging roof is medium-grain sandstone. The direct floor is sandy mudstone and the lower floor is mudstone. The fall head of fault Zhang is about 120 m and this leads to the docking between 7# coal and the 8th limestone of the footwall. The width of fault Zhang is about 3 m.

The design and making of similar model

This test was based on the similarity theorem (Li, 1988). The similar material of the rock was composed of fine sandstone and the calcium carbonate meanwhile gypsum were used as cement. Then the best similar ratio of each model layer was achieved after repeatedly adjusting material. Finally, the model was built up. In addition, the fault zone was composed of mica powder and fine sandstone and there was no cement to achieve the loose characteristics of the fault zone.

Selection of similarity constants

The geometric similarity coefficient of similar model can be written as α_l. $\alpha_l = 1/100$. The density similarity coefficient can be written as α_γ. $\alpha_\gamma = 0.6$ .The stress similarity coefficient can be written as α_σ . $\alpha_\sigma = \alpha_l \times \alpha_\gamma = 0.006$. The similarity coefficient of strength equaled to which of the stress. The time similarity coefficient can be written as α_t . $\alpha_t = \sqrt{\alpha_l} = 1/10$.

Based on the similarity coefficient, the size of similar model was 4 m $\times$ 0.4 m $\times$ 1.5 m (length $\times$ width $\times$ height). This was equivalent to a height of 150m rock strata including a height of 61 m strata under the coal floor and a height of 83.5 m strata above the coal roof. In order to ensure the stability of the model and fault after the pressurization, the fault zone did not extend to the top of the model. The extension height of fault Zhang was 120 cm and the remaining height was covered by horizontal strata. The model was shown as fig.1. The uniaxial compressive strength of the similar material and the rock strata were shown as table 1.

Fig.1 *Similar material model*

Compensating load calculation

The test can only simulate the weight of 83.5 m height strata above the coal roof. The average buried depth of 7# coal was 450 m so the non-simulated strata needed the compensating load to be replaced. The compensating load formula can be written as Eq. (1).

$$p = s \times (\rho H \alpha_o - \rho \alpha_\gamma h) \tag{1}$$

where *P* is compensating load (KN); s is the cross-sectional area of the model (m^2); ρ is the average density of the strata (kg/m^3); *H* is the buried depth of the 7# coal (m); α_o is the stress similarity coefficient; α_γ is the density similarity coefficient; *h* is the height of the simulated strata (m). Put the parameters into Eq. (1) and the calculation of compensating load was 89.25 kN.

Table 1 *Similar material and compressive strength of prototype rocks*

Number	Strata	Uniaxial compressive strength of strata (/MPa)	Uniaxial compressive strength of similar material (/MPa)
1	7#coal	8.20	0.09
2	siltstone	49.60	0.30
3	sand and mud interbedding	31.60	0.19
4	fine sandstone	63.00	0.37
5	medium sandstone	72.48	0.42
6	mudstone	28.41	0.17
7	4th limestone	128.00	0.72
8	8^{h} limestone	53.82	0.31
9	9th limestone	165.7	0.92
10	10^{h} limestone	53.82	0.31
11	12th limestone	112.00	0.64
12	14th limestone	90.10	0.51

Similar simulation tests

The arrangement of displacement measurement points

In order to study the stability of tensional fault, the displacement characteristics of coal roof and the rock mass of the opposite wall were tracked and monitored with the reducing of coal pillar. There were 4 horizontal measuring lines and 115 displacement measurement points. In the horizontal direction, the displacement measurement points were arranged in the depth range of 5 cm, 15 cm, 20 cm and 50 cm above the coal roof spacing of 10 cm. Meanwhile, the measurement points were arranged in spacing of 5 cm near the fault zone. The positions of measurement points were shown as fig.2.

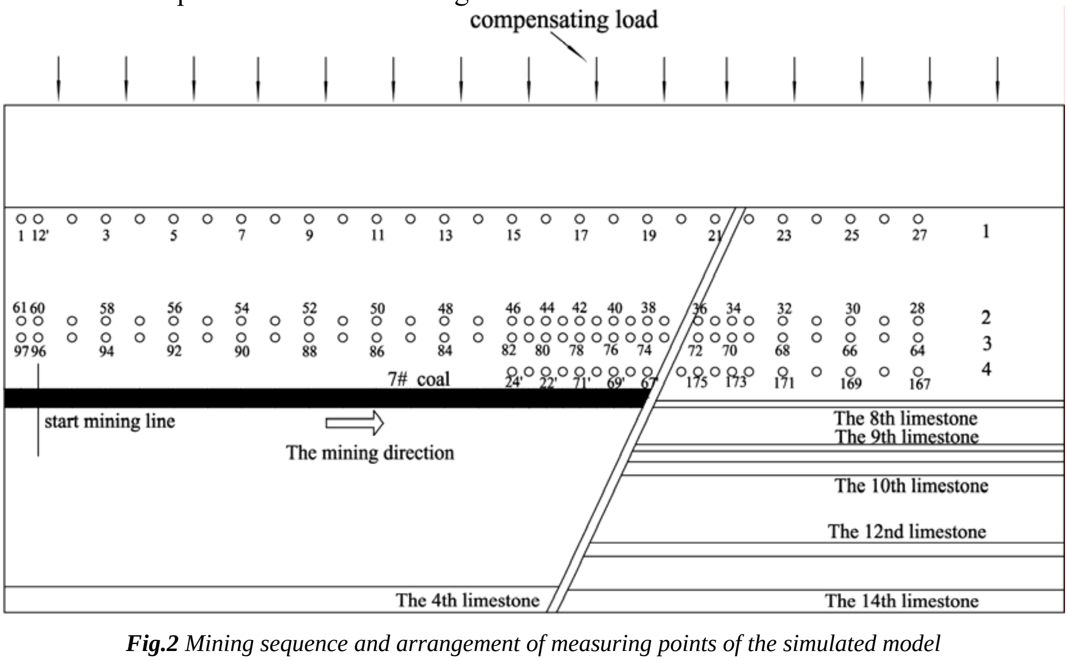

Fig.2 *Mining sequence and arrangement of measuring points of the simulated model*

Mining process

The mining direction of 7# coal was from left to right advancing toward the fault. The width of reserved pillar on the left border was about 1 m. The first mining width was 10cm,then the mining width was 5 cm at intervals of two hours. The total mining width was 175 cm and the final coal pillar width was 5 cm. Mining sequence was shown as fig.2.

Analysis of simulation results

The range of sinking basin was getting larger with the reducing of coal pillar as fig.3 to fig.5 shown. The shape of sinking basin was the bowl type at first then transferred to the groove when the transition of mining space was from inadequate to supper full. The displacement of both working face ends was the minimum while the displacement of central goaf was the maximum.

The displacement of the 3rd measuring line appeared obvious change when advancing 80cm and the maximum vertical displacement was 4.75 m. The displacement curves were shown as fig.5. The displacement of the 2nd measuring line appeared obvious changes when advancing 105 cm and the maximum vertical displacement was 4.62 m. The displacement curves were shown as fig.4. The displacement of the 1st measuring line appeared obvious changes when advancing 150 cm and the coal pillar width was30cm. The maximum vertical displacement was 4.62 m and the displacement curves were shown as fig.3. It indicated the caving scale of coal roof was getting larger form top to bottom. The nearer the measuring line from the coal seam was, the larger the displacement was. While the coal pillar width was 30 cm, the displacement of 1st measuring line which was the furthest line from the coal roof appeared mutation. This indicated the hanging wall rock mass became large sinking resulting the hanging wall dislocation along the fault zone. Finally, the fault zone became activation and it may lead to the water-inrush accidents from the lower confined aquifer along the fault zone.

In order to observe the displacement of rock mass near the fault zone, the 4th measuring line above 5 cm from the coal seam was arranged. The vertical displacement curves were shown as fig.6. The displacement of hanging wall was getting larger with mining while the displacement of foot wall changed slowly. When the coal pillar width was 30 cm, the displacement between two sides of the fault zone appeared obvious differences. The displacement difference was 0.14 m and the final value was 0.205 m when the model reached the stable state. When the coal pillar width was less than 30 cm, the dislocation between two sides of the fault zone was very obvious.

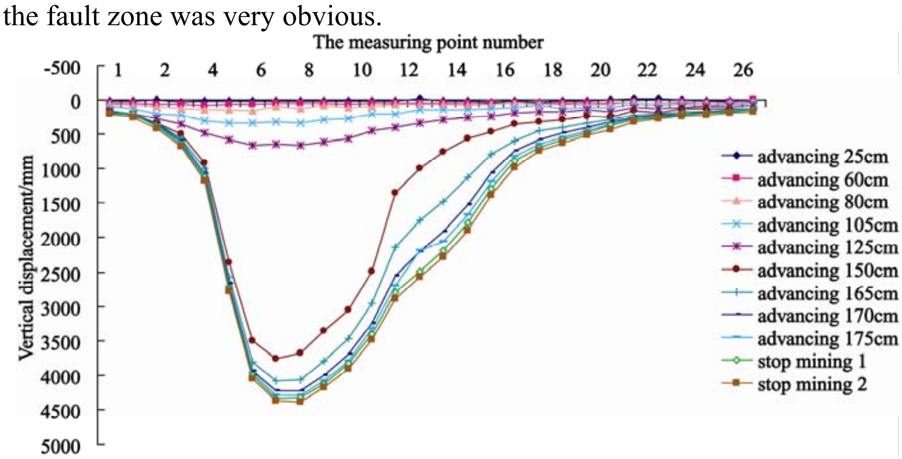

Fig.3 *Changing curves of vertical displacement of the 1st measuring line*

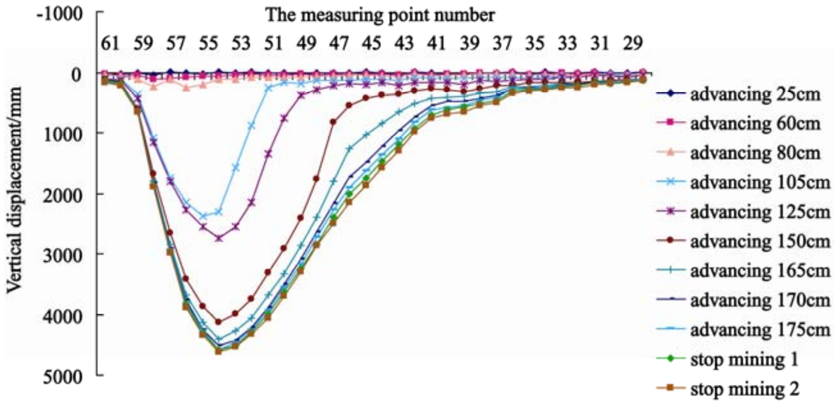

Fig.4 *Changing curves of vertical displacement of the 2nd measuring line*

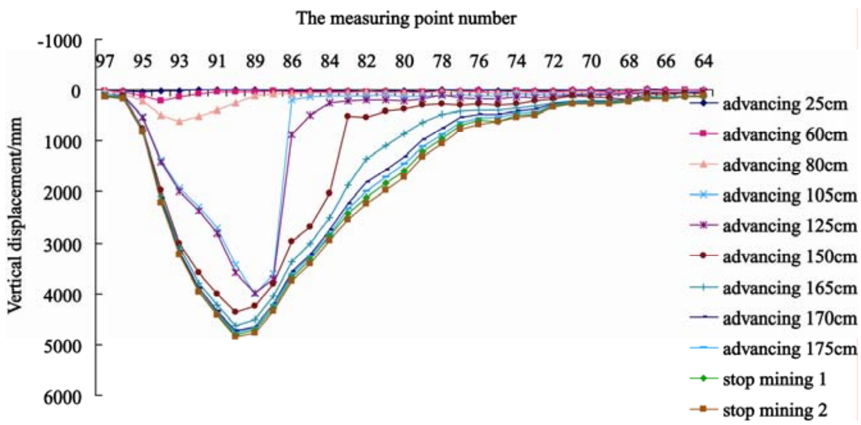

Fig.5 *Changing curves of vertical displacement of the 3rd measuring line*

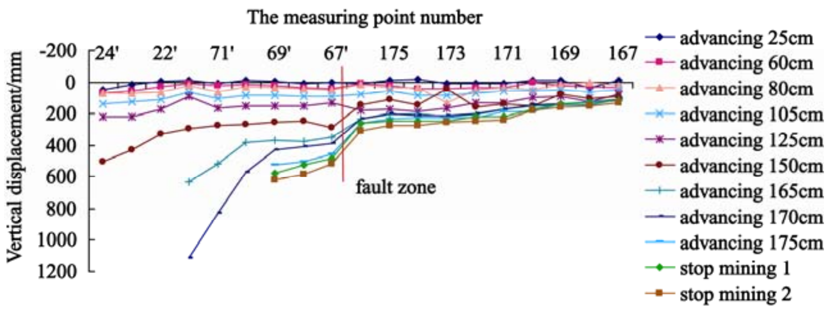

Fig.6 *Changing curves of vertical displacement of the 4th measuring line*

Conclusions

(1) The vertical displacement of coal roof of the two fault walls was tracked and monitored with the reducing of coal pillar by similar material simulation experiment. The results show the state of fault zone finally transferred to instability.

(2) Based on the similarity theory, the model size was transformed to the real size, then, we conclude the critical coal pillar width less than which the fault zone happened to activation was 30 m.

(3) The coal pillar width should be at least 30m for security and taking full advantage of energy. We have achieved the expected effects and the 7#coal has been mined safely. The results have good practical value.

Acknowledgements

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