Numerical simulation of the stress distribution in a coal mine caused by a normal fault

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Abstract. Luling coal mine was used for research using FLAC3D software to analyze the stress distribution characteristics of the two sides of a normal fault zone with two different working face models. The working faces were, respectively, on the hanging wall and the foot wall; the two directions of mining were directed to the fault. The stress distributions were different across the fault. The stress was concentrated and the influenced range of stress was gradually larger while the working face was located on the hanging wall. The fault zone played a negative effect to the stress transmission. Obviously, the fault prevented stress transmission, the stress concentrated on the fault zone and the hanging wall. In the second model, the stress on the two sides decreased at first, but then increased continuing to transmit to the hanging wall. The concentrated stress in the fault zone decreased and the stress transmission was obvious. Because of this, the result could be used to minimize roadway damage and lengthen the time available for coal mining by careful design of the roadway and working face.

1. Introduction
Fault zones are one of the commonest geological structures in the mines. They must be faced and solved in coal mining (Toprak Selami et al. 2015; Ma FH et al. 2011). A fault zone is mainly composed of broken rock whose caking propertied are poor and cohesion is low. Its geological characteristics differ from those of relatively complete rock. The fault zone has obviously been affected by coal mining. To a complex structure coal mine, the two sides of the fault zone showed different damage characteristics. Because of this, it is important to study the roadway deformation by simulating and analyzing the stress transition process on its two sides. By using two different working face coal mining models, the stress transmission regularity of the fault zone can be determined.

With the mining process, the integrity of the original rock was destroyed. The two walls of the fault showed different mining effect because of the obvious different stress transmission (TANG Dong-qi et al. 2010; Wu Ji-wen et al. 2009). Previous studies of fault zones, were mostly using numerical simulation and similar material simulation, which included the stress and support technology to front section of working face, the destroy studying on the fault zone and the floor and water conduction of fault zone (Cheng J L et al. 2013; Jiang Z Q et al. 2014; Kang Y S et al. 2014; Xia Binwei et al. 2016). Studying on the stress transmission influence of the fault zone, especially considering the working face direction and tendency of fault and effect of stress transmission were few.

2. Coal mine introduce
The western boundary of the coal mine is 6-7 and 13 exploration lines, which adjacent to the mining coal mine and the eastern boundary is F32 fault. There are still another boundaries, separately are
shallow 10 coal seam outcrop and the ground projection of deep -800m. The coal mine is about 8.2km long, and 3.6km width. The exploration area is 29.5km². The mine design annual production capacity is 1.500 thousand tones and service period about 66 years. Take cross-heading mine shaft level to develop, along the inclined direction is divided into three levels of exploitation including -400, -590 and -800m.

The mine is in the North China straitgraphic system and the Carboniferous Permian strata are divided into 11 coal groups, of which 8# and 10# coal seams are the main mining horizons.

The mine is in the southern region of the North China Coal-accumulation Zone, in the Su-Dong syncline which on the south of the Xu-Su arc nappe structure zone in the Huaibei coal field. The main tectonic framework of the mining area was formed during the Indosinian and Yanshanian. The tectonic stress continued to increase, causing the deformation and destruction of the Su-Dong syncline. Thus the mine has a complex geological structure, and the deformation and destruction of the roadway are serious. Studying the stress distribution on the opposite sides of the fault under mining conditions is helpful in understanding the regularity of the stress transmission, enabling protection the roadway and the working face. In this paper, the regularity of stress transmission was studied using numerical simulation to analyze the effects of the fault while mining is under way at working face.

3. The establishment of the model

3.1. Model design

Take the horizontal geological model of the coal mine area as an example, the average coal seam thickness is 4m, and the buried depth is 800m and the width of the working face is 150m. The mine used disposable full height mining way and the management of the roof adopt free fall model. Geological model geometry characteristics are 400m long, 300m wide, 100m high. The obliquity of the fault is 65 degrees with 5m width. And the entire simulating strata dip angle is 0 degree. The model is divided into a grid of 486000. Boundary condition setting: the bottom is fixed, the horizontal direction is limited, and the top is the free boundary which accepts the load stress of the overlying rock and soil. The geological model and grid model are shown in Fig. 1 and Fig. 2.

3.2. Constitutive models and the selection of physical and mechanical parameters of rock mass

Using Mohr-Coulomb plastic constitutive model and Mohr-Coulomb yield criterion, the physical properties and mechanical parameters of different rock mass were achieved according to the drilling and laboratory rock testing. Bulk modulus and shear modulus can be converted according to the
following formula (Peng Wen-bin 2007; Wu Jia-long 2009), Eq. (1)-(2).

\[ K = \frac{E}{3(1 - 2\mu)} \quad (1) \]
\[ G = \frac{E}{2(1 + \mu)} \quad (2) \]

Parameter \( K \) — bulk modulus; \( G \) — shear modulus; \( E \) — elastic modulus; \( \mu \) — poisson’s ratio.

| Rock attribute         | Elastic modulus (GPa) | Bulk density (kg/cm²) | Tensile strength (MPa) | Cohesion (MPa) | poisson’s ratio | Internal fraction angle (°) |
|------------------------|-----------------------|-----------------------|------------------------|----------------|-----------------|----------------------------|
| Fault                  | 8                     | 2.0                   | 0.3                    | 0.6            | 0.24            | 22                         |
| Coal                   | 4                     | 1.42                  | 0.3                    | 1              | 0.35            | 25                         |
| Silt stone             | 16                    | 2.56                  | 3.8                    | 7.5            | 0.25            | 40                         |
| Fine-sandstone         | 13                    | 2.65                  | 4.5                    | 12.5           | 0.21            | 42                         |
| Medium sand            | 14                    | 2.65                  | 3.5                    | 7.1            | 0.23            | 38                         |
| Coarse sand            | 15                    | 2.65                  | 3.3                    | 8.5            | 0.22            | 33                         |
| Mud stone              | 12                    | 2.65                  | 1.64                   | 3.5            | 0.22            | 33                         |
| Sandy mud stone        | 16                    | 2.65                  | 2.64                   | 5              | 0.15            | 34                         |
| Al mud stones          | 14                    | 2.84                  | 2.0                    | 3.8            | 0.21            | 33                         |

3.3. Initial stress and boundary conditions

By applying a gradually changing internal stress to the geological body, the changing regularity of the initial stress was simulated. The initial stress is consistent to the stress of the geological body that was achieved by the field test and laboratory rock testing. The lateral stress (horizontal stress) is calculated using side pressure coefficient without considering the structural stress (Liu You-rong; Tang Hui-ming 1999), Eq. (3)-(4).

\[ \sigma_{w} = \gamma H \quad (3) \]
\[ \sigma_{h} = \frac{\mu}{1 - \mu} \gamma H \quad (4) \]

Parameter \( \gamma \) — Bulk density; \( H \) — the depth of the unit grid; \( \mu \) — poisson’s ratio.

The vertical load stress of the each geological unit is the weight stress of the overlying rock. And the lateral stress (horizontal stress) was considered.

4. Numerical simulation results analysis

The stress nephogram of the rock mass was obtained through the simulation to different mining model of the working face. Stress redistribution was different on the sides of fault caused by the two different relationships between tendency and the mining direction. The simulation result showed the step of the first roof pressure is 30m; the step of cycle pressure is 20m. Several representative steps are selected to analyze the stress change regularity under the influence of fault.

4.1. The stress distribution characteristic analysis of the model 1

Reversing the fault tendency while the working face is in the hanging wall of the fault, the stress distribution on both sides of the fault was different. When the working face was advancing 50m ahead (the distance from the fault is 120m), both sides of the fault zone stress had no significant difference.
(Fig. 3a), the stress value were about 25MPa. When the working face was advancing 70m ahead (the distance from the fault is 100m), obvious stress difference appeared on both sides of the fault zone. And it became more obvious when the working face was advancing 110m ahead. The maximum stress of the hanging wall changed from 28.3MPa to 32.8MPa near the fault when the working face was promoting from 110m to 150m (the distance from the fault is 60 to 20m). Meanwhile the stress of the foot wall was hardly any influenced, and was still maintaining about 25MPa. When the working face was advancing 150m ahead (the distance from the fault is 20m), the maximum of the stress appeared near the fault, the value was 32.8MPa. The result was that the stress concentrated on the hanging wall of the fault and near the fault, and changed when the working face was in progress. And the stress of the foot wall was hardly any change and still maintained about 25MPa. The stress of the hanging wall hasn’t been transmitted to the foot wall.

![Fig. 3a, b, c, d](image1)  
| a | b | c | d |
|---|---|---|---|
| The working face advancing 50m ahead | The working face advancing 70m ahead | The working face advancing 130m ahead | The working face advancing 150m ahead |

**Fig. 3** the vertical stress nephogram while working face mining Reversing fault tendency

![Fig. 4](image2)  
**Fig. 4** the vertical stress change Fig. on the sides of the fault

Fig. 4 showed that the stress in the hanging wall near the fault was concentrated and had no obvious stress transmission to the foot wall. The maximum concentration stress is 32.8MPa, and the stress concentration factor was 1.31.

4.2. The stress distribution characteristic analysis of the model 2

Setting the same rock strata combination and buried depth of coal seam, along the fault tendency while the working surface is in the foot wall, the stress distribution regularity on both sides of the fault was different from model 1. When the working face is advancing 50m (the distance from the fault is
120m), both sides of the fault zone stress appeared to decrease and the reduction continued until the working face is advancing 70m (the distance from the fault is 100m) (Fig. 5). The concentrated stress appeared on the sides of the fault when advancing 110m (Fig. 6). However, the stress was beginning to decrease when advancing 150m (the distance from the fault is 20m) (Fig. 6). And the stress was transmitted to the hanging wall, and the stress of the hanging wall changed obviously. The vertical stress change on the sides of the fault was obtained (Fig. 6).

![Fig. 5 the vertical stress nephogram with working face mining along fault tendency](image)

From Fig. 6, the stress of the fault zone decreased at first, then increased. The stress transmitted to the hanging wall when the working face is advancing 150m (the distance from the fault is 20m) and the stress of the fault zone decreased again. The stress of the foot wall changed from 40.3MPa to 36.3MPa, and the stress of the hanging wall obviously changed from 25.1MPa to 29MPa. The influencing and changing rang of the hanging wall was about 30m.

5.Conclusions and recommendations
(1) The coal mine geological condition is complex. The geological model was constructed through laboratory rock test combined with regional geological background. Two different working face models were established and the stress change law of the fault zone was simulated.
(2) The stress concentration was gradually increasing with mining of working face while the working face was located at the hanging wall. The stress mainly concentrated on the hanging wall...
but the foot wall was almost not affected. The result showed the fault zone plays a role in preventing the forward transmission of the mining stress while the direction of the working face and fault tendency was opposite.

(3) The stress concentration decreased at first, then increased with the mining of working face under the condition of along the fault tendency mining and the working face is on the foot wall of the fault. The stress transmitted to the hanging wall and the stress of the fault zone decreased again. The fault zone could not play a role in preventing the stress transmission and the stress on the foot wall became larger.

(4) The mining stress change regularity was obtained by the numerical simulation results. The roadway of a coal mine near a fault should be designed in the wall, in which the direction of the working face is consistent with the tendency of the fault reducing the mining stress and the destruction of the roadway.

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