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Mechanism of Water Inrush from Coal Floor Fracture in YongXia Mining Area Simulated by Numerical Simulation

Zhang Kai, Guangui Zou
State Key Laboratory of Coal Resource and Safety Mining, China University of Mining & Technology, Beijing 100083, China

Abstract Fracture water inrush is a new type of water inrush, the fracture is divided into three types based on its distribution: open fractures, closed fractures and guided into ascending fractures, the first and second type is called connected fracture. Characteristics of water inrush caused by fracture development were analyzed by Flac3D numerical simulation method. The results indicate that the region with the connected fractures has the largest of the shear strain increment, the connected fractures is helpful for fracture splitting, resulting into stronger fracture conductivity connectivity. Under the combined effect of vertical stress and water pressure, the relative displacement near the cracks is larger. Both sides of fracture displacement show different direction at the same time, the displacement direction of left fracture is the left; the displacement direction of right fracture is the right. The displacement at the same side of fracture is increased from top to bottom. Fracture are widened and expended into Connection fracture under the upward vertical pressure in the bottom and the powerful limestone water pressure, finally forming water inrush. In progressive liters of fracture, along with the advancement of coal seam mining, the goaf' two sides are the compressive stress, the roof is the tensile stress area, there are concentration belt located at the both sides of the crack, resulting in the serious damage in fracture zones ,the bottom deep fracture develop upward and connect with the fracture in the floor, so the fracture provide channels for water in Taiyuan group limestone into the mined-out area, resulting in progressive liters of water inrush.
Keywords fracture water inrush, numerical simulation, pressure, water inrush mechanism

Introduction

Yong Xia mining area is located in Henan province YongCheng city, within the territory of north and south long 55 km, 25 km wide from east to west and 1150km^2 exploration areas. Above 1000m level coal-bearing area more than 572km^2, proven coal reserves of 2.56 billion tons, most of them are high quality anthracite. Main mineral coal seam named C2 is threaten from bottom of Taiyuan group limestone water (Liu 2004). Yong Xia limestone water inrush characteristics is different from water mining area of north China, feicheng, jiaozuo, kailuan, fengfeng mining area are mostly caused by fault water inrush or thickness of water-resisting layer. Yong Xia limestone mine water inrush are has nothing to do with the fault or floor strata thickness (TWO2 coal seam is 80m from the lower limestone, it has enough thickness of waterproof layers), but by the native fracture water in floor strata. 1 times in 14 times larger water inrush caused by fault water inrush, the rest of the 13 TWO2 coal floor water inrush channel are sandstone and limestone fracture. There is no small fault near water inrush from the gap between the larger fault (about 30 m), mainly in more than 100 m (Liu et al. 2002). Each of the water inrushes caused enormous economic loss, but also buried a huge hidden danger to the safety in production.

In order to further understand the characteristics of mine water inrush, often adopt the method of numerical simulation to analyze. For example, in view of the fault water inrush, we have established in fault and without fault of the surrounding rock deformation and failure of mechanical model, analyzed of fault activation and guide the formation of water channel, influence on water bursting geological of under pressure mining for the stress (Zhang et al. 2010; Huang et al. 2013), the plastic zone in surrounding rock and the fault distribution in fracture of hysteretic water bursting characteristics, use the creep mechanics test method, the F0 fault material mechanics parameters for the numerical simulation calculation, using Flac3D numerical simulation software, flow of mining activities affected by the fracture leak

creep-solid coupling simulation and calculation (Liu et al. 2012; Shen et al. 2013). Aimed at high confined water damage process and the water inrush mechanism of bottom plate under the action of finite element numerical simulation software ANSYS, respectively, the complete floor strata under the conditions of different water pressure, bottom fracture rock bottom stress in the process of working face advancing floor, to simulate the changing situation so as to analysis whether the conditions of water inrush (Cao 2006; Li 2013). Based on the mine transient electromagnetic method for mine 71309 face plate containing water detection results, abnormal coal floor strata containing water distribution area, combining with the actual geological conditions, by means of Flac3D and fluid-structure coupling numerical model is set up, and to analyze the results of numerical calculation (Guo et al. 2013). Mining dynamic instability of rock mass and the seepage mutation is the direct cause of the mine water inrush. With the thread of damage evolution of rock mass, considering the heterogeneity of rock mass, the coupling effect of seepage and deformation, put forward the fluid-structure coupling constitutive relation of rock damage process under the condition. According to the reality of the fan area mining collapse column water bursting, the numerical simulation reproduces the whole process of water inrush occur, and probes into the mechanism of water inrush (Zhu et al. 2009). For 1301N Longgu mine working face mining depth, mining geological conditions of the large span, the 3-d numerical simulation software Flac3D, 3 coal seams mining working face roof are analyzed characteristics of the distribution of vertical stress and the plastic zone of its water fractured zone height simulation study (Liu et al. 2013).

From the study above, it can be seen that the water inrush caused by fracture is less analysis. In this paper to Yong Xia mine mining area Cheji mine as an example, combined with the analysis of the lithologic characteristics of coal floor, the floor fractures are divided into open fractures, closed fractures and guide into ascending fracture. Using Flac3d numerical simulation method, basing on different fracture occurrence characteristics analyses of the fractured the characteristics of water inrush.

Engineering geological survey in the study area

Yong Xia mining area is located in HuangHuai plains, the coal bearing strata in the mining area belong to North China type Carboniferous, Permian coal-bearing strata, overlying new strata are 200m~400m thick. Taiyuan group total thickness of 140~160 m, including 11 layers of limestone (L1~L11), divided into (L7~L11) in the upper and the lower section (LI~L6), including L8, L2 two layers of limestone deposition thickness stability, karst development, strong capability, fast hydrostatic pressure transmission, initial water level of the limestone of the upper is 27.32~28.70m, the annual range is 0.70~0.95m. And the Ordovician limestone water level is 27.04~28.59m, in range of 1.01m. L8 limestone distance coal seam mining coal seam TWO2 recently about 80 m, the water pressure is high, it has the same water level and the Taiyuan group limestone water pressure, the Ordovician limestone water supply Taiyuan group limestone water in some way, is the main simulation calculation of limestone aquifer. But TWO2 coal seam Taiyuan group limestone distance of about 50 m recently, because of Taiyuan group limestone of hydrogeological situation was complex, deep layer within the conducting limestone water channel, also can be treated as limestone aquifer. So the simulation to choose Taiyuan group limestone aquifer from 2 seam distance is 50 m. The strata from the bottom of the TWO2 coal to Taiyuan group limestone, mainly consists of mudstone, the average thickness is about 14 m. In the upper part is given priority to with silty sand rock, an average of 40 or so. Considering the mudstones exist Tai Hui surface confined water conductivity raises fracture zone, effective thickness of cement rock in 10 m, silty sand rock in 40 m.

The calculation model and calculation parameters

The calculation model

For the study of slab cracks, the mechanism of water inrush in summer mining TWO2 coal seam as the background, embedded depth of coal mining working face in -450 m, the corresponding Taiyuan group limestone buried deeply -500 m. Model including TWO2 coal seam and roof and floor rocks, takes an averagedip angle of coal seam of 15 , thickness of coal seam 3 m, working face length of 180 m, the thickness of marine facies mudstone is 10m, the thickness of medium-fine sandstone is 42 m. Coal floor develops faults. Model of the upper boundary, rock gravity stress Taiyuan group limestone under the influence of pore water pressure, as shown in fig. 1.

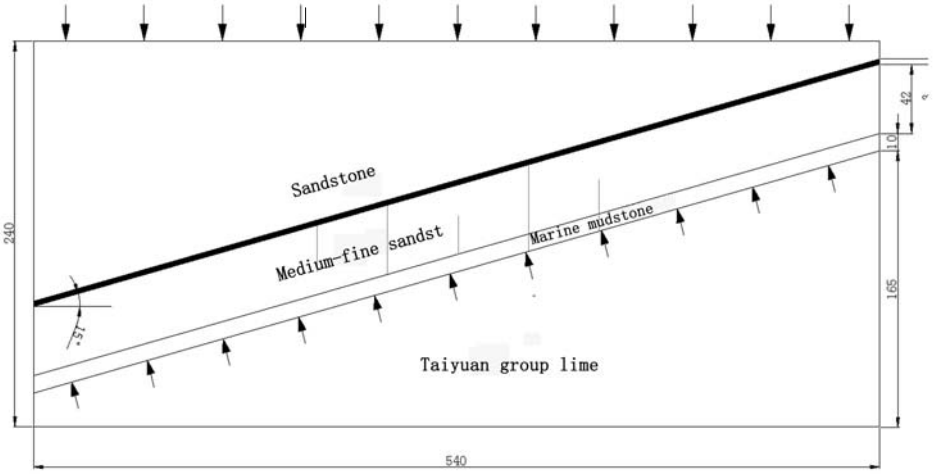


Fig. 1 *A model for the engineering concept*

Established Flac 3D three-dimensional calculation model conducts numerical simulation. Model along the strike is 300m long, along the slope 540m wide, the model height is 24 m. 3D models were divided into 87480 3D units, a total of 93940 nodes, calculated by the computer generated 3D model grid. The joint use weak intercalation and contact surface (Interface) to simulate.The model side limits level mobile, bottom limit vertical movement, applying vertical load simulation model of the upper weight of overburden.The main mechanical parameters of rock in the study area are Based on field geological survey and related research of rock mechanics test results

Simulation results and the analysis of water inrush from floor cracks

Because of the development of base plate fracture, and the influence of coal seam mining, formed the water channel, causing bottom fracture water inrush. There usually have three conditions: the open fractures, closed, the fracture water inrush water inrush and progressive litres of water inrush, the top two cases are due to already cutting face and aquifer between layers of water inrush caused by fracture, fracture water inrush can be called a connection. So the numerical simulation backplane fracture water inrush can be divided into two cases: connect the fracture water inrush and progressive litres of water inrush.

Connecting the fracture water inrush of numerical analysis

As shown in fig. 2 is the displacement of coal seam tilt direction along the X-direction at the distance of 45m from open-off cut when mined length 90 m, vertical fracture toward the direction of the displacement, it also can be seen from the picture on the relative displacement is bigger near the cracks, cracks in the vertical stress and pressure took place expansion under the combined action.

In order to better simulate the principle of connecting fracture water inrush, this paper established a special model with only one fracture, the fracture cutting seam floor and Taiyuan Formation Limestone, and 45 m from open-off cut, crack on both sides set up 22 monitoring points, 11 layer. White dot on the map indicates monitoring points, numbers indicate the layers. Each monitoring point will monitor the displacement in the X direction at all. Same layer monitoring relative displacement on the X direction can be said to expand the width of the cracks in the layer.

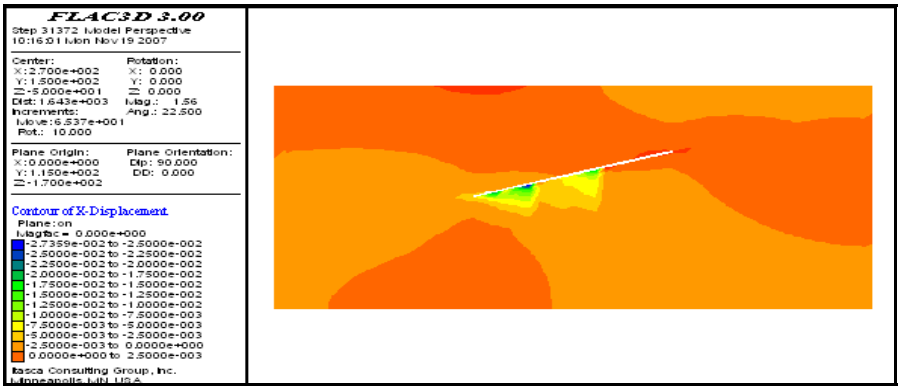


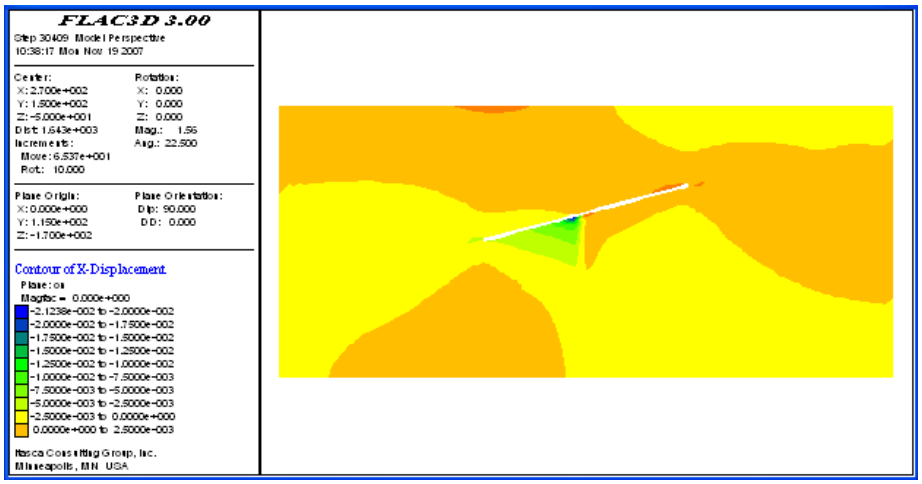
Fig. 2 *Mined lengths of 90 m, the displacement of coal seam tilt direction along the X-direction at the distance of 45 m from open-off cut*

As you can see from fig.3(a), the place in fracture is also large displacement, on both sides of fracture displacement in a different direction, the left displacement direction of fracture is to the left, and the right displacement direction of fracture is to the right. The same side for fracture, displacement increases gradually from top to bottom. As you can see from fig.3(a), due to the vertical stress and pore pressure of Taiyuan Formation Limestone, plus mined effect, the crack expansion occurs, and the more powerful the nearer to the working face is expanding.

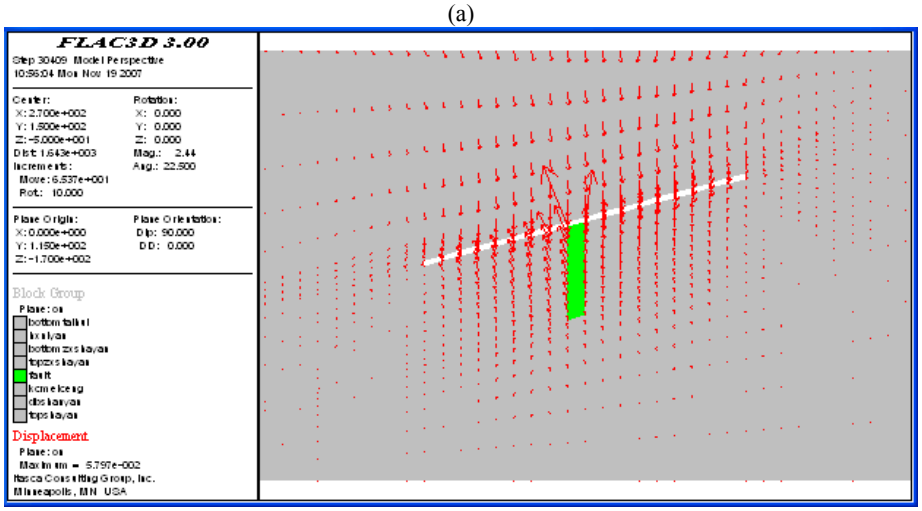
Fig. 3(b) is the displacement vector diagram at the distance of 45 m from open-off cut when mined length 90m, the crack location are shown in green, the figure can be seen on the fracture of the left side of the node displacement direction to the left and right fracture on the right side of the node displacement direction. Displacement of the upper fracture is larger than the bottom. From the figure can also be concluded that the expansion of the cracks occurred, and the expansion of the bottom cracks is more powerful.

When mining 90 m, X direction of the monitoring displacement shown that displacement is larger, and displacement decrease gradually from top to bottom, among them in the first layer to the left of the displacement of monitoring points is 0.02124 m, the left side of the 11th layer displacement of monitoring points is 0.0004138 m, displacement direction to the left. Monitoring stations on the right side of the small relative to the left of the displacement of monitoring points, Layer1 of the displacement of monitoring points is 0.005746 m; the direction to the right, 11 layers of the displacement of monitoring points is 0.005746 m, to the right direction.

Two of the same layer of the relative displacement of monitoring points can be said the width of crack expansion, we can see that the first layer extension width is 0.026986 m. The width is becoming smaller along with the direction to the fracture bottom, it is seen from fig. 4.



(a)



(b)

Fig. 3 *Mined length of 9 0m, the displacement of coal seam tilt direction along the X-direction at the distance of 45m from open-off cut,(b): Mined length of 90m, the displacement vector diagram at the distance of 45 m from open-off cut*

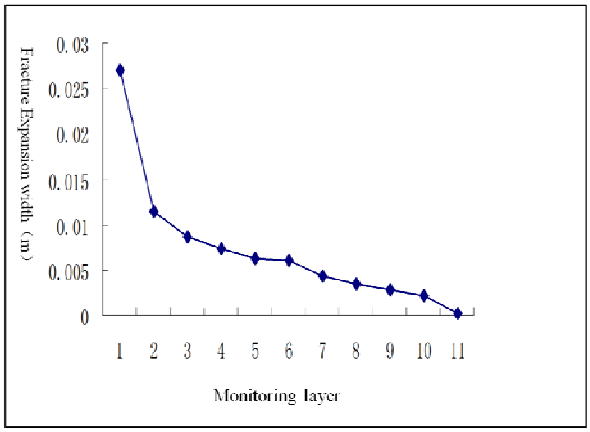
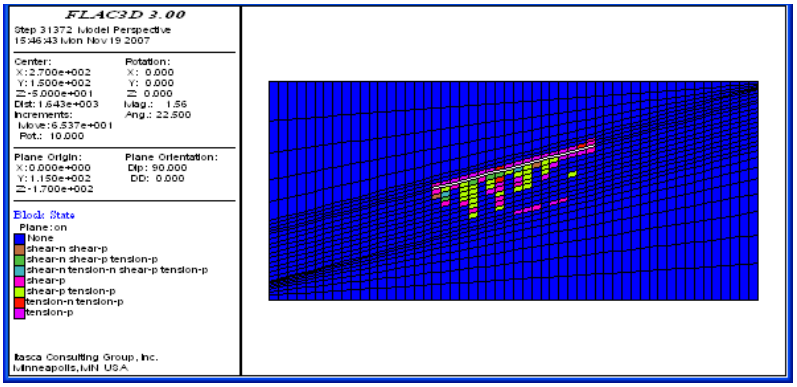


Fig.4 *crack expansion width of each monitoring layer*

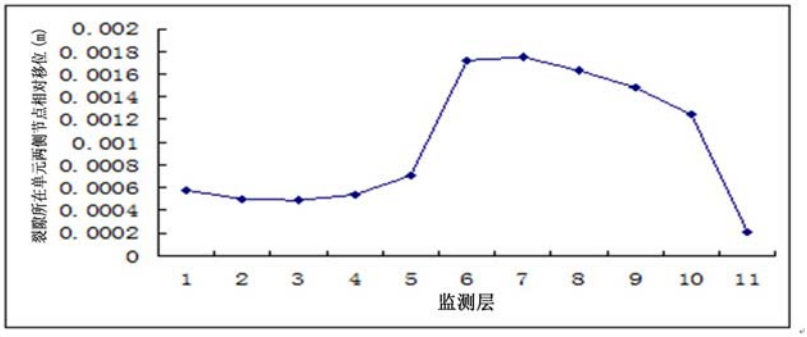
From the above analysis, under the joint action of Normal stress and Taiyuan Formation limestone water pressure, the coal seam mining can affect the distribution of stress, particularly in the fracture zone, which can cause fracture splitting. So that the native closure or slightly open fracture expansion, make originally open fractures to expand further, crack width increase, to lead the water channel. The backplane native cracks, and cut into the limestone, the mechanism of water inrush are as follows: In goaf roadway bottom or vertical upward pressure and powerful limestone water pressure, crack open or expansion, resulting in limestone water inrush, forming open fracture water inrush or water bursting tensile fracture closure.

The progressive guide liters of water inrush numerical analysis

With the advance of coal mining, as well as the impact of coal seam floor cracks, making the seam floor stress distribution has changed. With the impact of coal seam mining in the mined-out area on both sides produced a compressive stress concentration area, the compressive stress of up 18.52MPa. Seam roof produces tensile stress area, up to 3.1695 MPa, distributed more rules. Because of the cracks on the bottom coal seam, the stress concentration zone produced four, each with a maximum tensile stress in the stress concentration is 3.1695 MPa, it can be seen from the graph of tensile stress concentration zone located on both sides of fracture, due to fracture zone within the medium softer, so that both sides of the fractured zone of rock bearing too much stress, so the formation of four stress concentration zone. This makes in fracture both sides zones of the rock damage more serious, thus connect with fracture, as seen from fig. 5 (a).



(a)



(b)

Fig. 5 *(a) Mined length of 90 m, the broken area along the tendency of the coal seams at a distance of 45m from the open-off cut,(b): Lower fracture in X direction of unit monitoring relative displacement diagram*

When mined length is 50 m, rock at a distance of 45 m from the open-off cut has been damage at a distance of 45 m; the floor damage maximum depth is 25 m. The damage area is mainly

distributed at the both side of the crack area. With the increase in the length of mining, coal seam floor failure depth increase further, when it reaches 90 m, the maximum damage depth of 40 m. Undermine regional and fracture connectivity, so as Taiyuan group limestone water into the gob provide channels.

In order to further confirm the bottom guide crack will rise up, this paper established a special model with only a fractured, and the fracture cut aquifer of Taiyuan Formation limestone, but did not cut through the seam floor. And 45 m from open-off cut, 11 layers on both sides of fracture and set up 22 monitoring points, Lower part of the fracture is located on the 5th floor of 11 measuring points, white said monitoring stations on the drawing, number shows how many layers. Each monitoring will monitor the displacement in the X direction at all.

When mined 90 m, X direction of the monitoring displacement are shown that the amount of displacement of each monitoring point is not large, this is mainly because the simulation is based on the premise of small deformation, fracture also not cutting through coal seam floor.

It can be seen from the relative displacement of peer monitoring, from 1 to 11 layers, relative displacement decrease first and then increased, and decreased again, as seen in fig. 5 (b).

If there is no coal floor fracture zone, the monitoring of the X direction displacement will decrease with the increase of depth. And from the results of this simulation, monitoring points from 1 to 3 layers X direction relative displacement decrease gradually, from 3 to 4 layers X direction of the relative displacement increases, it shows that the fracture crack up. Then increased from 5 to 6 layers of relative displacement, relative displacement is larger in the upper fracture X direction, so as to provide the conditions for the development of crack up. Then with the increase of the depth, the relative displacement decreases. So under the influence of fracture water pressure in Taiyuan group limestone will be upward development, thus may conduction coal floor damage zone formation of the fracture zones, provide channels for Taiyuan group limestone water into the mined-out area.

From the above analysis, we can draw the mechanism of progressive guide of water inrush. Upper the limestone, they are the mudstone and the sandstone that the fracture in coal floor did not arrive, that format of confined water of the original belt. Because of the rock mass stress released after coal seam mining and mining pressure, the effect of the upper plate forming fracture zone. In the mining process due to the common role of mine pressure and water pressure, at the bottom of the guide will rise crack up, breakthrough came after destruction, and floor are formed water channel, resulting in progressive water inrush.

Conclusions

Fracture water inrush is a new type of water inrush, the key lies in the formation of original crack and development situation of the mining caused fractures. Using Flac3D numerical simulation method, combining with the drilling data, different fracture occurrence characteristics for water inrush were analyzed. Simulation results show that:

(1) The backplane native cracks, and cut into the limestone, the mechanism of water inrush are as follows: in the goaf roadway at the bottom of the vertical upward pressure and powerful or limestone water stress, cracks open or expansion result in limestone water inrush, forming an open fracture water inrush or closed.

(2) According to the numerical simulation analysis, the progressive rising water inrush type, upper limestone and mudstone and sandstone fracture in coal floor did not arrive the formation of confined water of the original fractured belt. Because the rock mass stress released after coal seam mining and mining pressure, the effect of the upper plate formed fractured zone. In the mining process due to the common role of mine pressure and water

pressure, the fractures at the bottom of the original fractured belt will rise and crack. Breakthrough came after destruction, and floor formed a water channel, resulting in progressive water inrush.

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