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Research on Prediction of Instability Failure for Gassy Coal Sample in Different Confining Pressure Based on Microseism

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Abstract

According to the rock failure damage theories and the gas-solid coupling method, used RFPA^{2D}—GasFlow soft code to study the characteristics of microseism in time and space for gassy coal sample in different confining pressure. It is shown that there is some microseism precursory before main shock. Basing on the characteristics of microseism precursory events amount in time can be warned in advance, and basing on the characteristics of microseism precursory events produced by tension stress in space ,there is can divide potential failure danger zone. It is shown that the divided results for potential failure danger zone are exactly, and with the increment of confining pressure, the accuracy of divided results on potential failure danger zone become higher. It is found that the potential failure danger zone consistent with crack initiatory zone by contrasted potential failure danger zone to crack development process, and with the increment of confining pressure, the consistency become higher.

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Keywords: gas-solid coupling; confining pressure; heterogeneity; main shock; microseism precursory; numerical tests

1 Introduction

Microseism monitoring technology is very active in rock mechanics and mine safety field in recent years. Compared with traditional technology, microseism monitoring technology possesses remote, dynamic, three dimension and real time characteristics, and it is can analyze the failure size and character basing on microseism monitoring results. Microseism monitoring technology provides a new monitoring tool and method for coal and gas outburst. In coal mine, coal seams are mostly including gas and bearing ground stress at the same time. So coal seams are mostly in triaxial stress state. And as we all know, coal is a heterogeneity material, so the results of experiment for microseism characteristics which ignore the heterogeneity of coal, the role of gas and confining pressure in failure process are lacking reliable basis for application of microseism monitoring technology. Basing on this, and on the base of consideration of coal and rock physical mechanics nature, the heterogeneity and the role of gas in failure process, dose some numerical experimentation research on the microseism characteristics of failure process of gassy

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coal samples under different confining pressure. Basing on the distribution characteristics of microseism in time and space it is can divide the potential damage danger area, provide theory base for the application of microseism monitoring technology in coal and gas outburst.

In $RFPA^{2D}$-GasFlow code, it is considered that microseism in the coal and rock distortion and failure process and the formation of micro-failure (damage) inside are directly correlative. So there is can anticipate there exist some necessary connection between microseism and damage of coal and rock. As an intuitionistic estimation, if ignore how high the energy of microseism is, and assume that each material mesoscopic unit failure has contribution to microseism, well then it is can draw a conclusion involuntary that in numerical simulation calculation there exist a direct proportion connection between unit damage quantity and microseism of rock. Based on this thought, it is can study microseism rule of coal and rock failure process through calculating the quantity of damage unit. In $RFPA^{2D}$-GasFlow code, used the damage unit number to represent MS counts, thus it is possible to use simple model simulate the microseism distributing rule of coal material.

1.1 Heterogeneity

For the research of failure process of gassy coal, in the former research, the heterogeneity character of coal weren't considered, in RFPA2D-GasFlow code, which this article adopts, has considered the heterogeneity character of coal sufficiently. Elastic modulus of unit, uniaxial compressive strength, poisson ' s ratio, gas content coefficient, permeability coefficient etc. distribute according to Weibull distribution, as can be seen in formula (1),among each parameter's meaning see references[1-3].

$$\phi(\alpha) = \frac{m}{\alpha_0} \cdot \left\{ \frac{\alpha}{\alpha_0} \right\}^{m-1} \cdot e^{-\left\{ \frac{\alpha}{\alpha_0} \right\}^m} \quad (1)$$

1.2. Solid-Gas Coupling Mathematical Model

Solid-gas coupling model of gassy coal which this article applies mainly includes three parts: seepage equation of gas flowing in coal, coal deformation equation and coupling equation of the coal damage under disturbing stress and breathability coefficient evolvement. These equations may be expressed as:

$$\alpha_p \nabla^2 P = \partial P / \partial t \quad (2)$$

$$(\kappa + G) u_{j,ji} + G u_{i,jj} + f_i + (\alpha p)_{,i} = 0 \quad (i, j = 1, 2, 3) \quad (3)$$

When the stress state or strain state of coal mesoscopic unit meets some appointed damage threshold, the unit begins damaging. It is can be known through the experiment, the damage will causes the coal sample breathability coefficient to increase suddenly, in the condition of uniaxial compression and uniaxial tension, the breathability coefficient of coal mesoscopic unit—the change of damage parameter D may be described by (4) and (5).

$$\lambda = \begin{cases} \lambda_0 e^{-\beta(\sigma_1 - \alpha p)} & D = 0 \\ \xi \lambda_0 e^{-\beta(\sigma_1 - \alpha p)} & D > 0 \end{cases} \quad \text{uniaxial compression} \quad (4)$$

$$\lambda = \begin{cases} \lambda_0 e^{-\beta(\sigma_3 - \alpha p)} & D = 0 \\ \xi \lambda_0 e^{-\beta(\sigma_3 - \alpha p)} & 0 < D < 1 \\ \xi' \lambda_0 e^{-\beta(\sigma_3 - p)} & D = 1 \end{cases} \quad \text{uniaxial tension} \quad (5)$$

(2) ~ (5) are solid-gas coupling mathematical model of gassy coal failure process which considers coal and rock distortion and damage and gas seepage. Among each parameter's meaning see references [1-3].

2 Numerical Simulations

2.1 Numerical Models

In order to consider the influence of heterogeneity, the m is be assumed 1.5. In order to reduce the influence which the randomness acts on the result, each numerical model is calculated for 10 times. The model size is 100mm×50mm, and the model is divided into 200×100 grids, numerical model can be seen from Fig.1. The physical and mechanical parameters and seepage parameters of numerical model can be seen in table1. The model adopts plane stress analysis, displacement control loading, 0.005mm is loaded in each step. Confining pressure are 2Mpa, 4MPa, 6Mpa and 12MPa. The surrounding of sample is airproof that is the gas flow is 0.

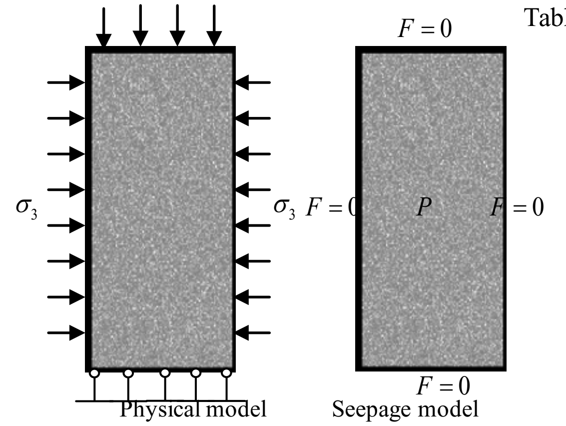


Fig. 1 Numerical model

Table 1 Mechanical and seepage parameters of model

Mechanical parameters	value
Homogeneous degree m	1.5
Elastic modulus mean value E. /GPa	30
Compressive strength mean value б. /MPa	200
Poisson ' s ratio μ	0.3
Breathability coefficient($m^2/MPa^2\cdot d$)	0.5
Gas content coefficient A	10
Pore pressure coefficient α	0.5
Coupling coefficient β	0.2

2.2 Numerical Results and Discussion

As can be seen in Fig.2, the microseism activity of sample is of stage character, in the pressure consolidation and linear elastic stage of coal, MS event is mainly produced by crack closing, sometimes there is rarely or even no microseism activity. In the expansion, transfixion and forming macroscopic failure stage of crack, a lot of microseism activities are produced. And it is can be known that the main shock occurs after stress peak, at this time macroscopic crack of coal sample has formed, and the coal sample loses bearing capacity. There is a lot of microseism precursor events before main shock happening, the microseism precursory events is more abundant when the main shock is drawing near, when the microseism precursory is formed in coal sample, its damage degree is low, the damage is local and the bearing capacity doesn't reach stress peak. It is clear that using macroscopic precursor accurately to predict can avoid the occurring of instability failure.

Based on distribution characteristics of microseism precursory events amount in time (step), it is can be warned in advance for the failure of gassy coal sample. But it is hard to determine the location or range of potential damage danger area, thus is unable to adopt effective prevention measures, and the purpose of microseism monitoring can not be reached. For realizing the purpose of accurate monitoring, it is need to combine the distribution characteristics of microseism precursory information in time with in space. In the nether content the process which uses time and space distribution characteristics of microseism precursory information to predict instability failure accurately of gassy coal sample will be introduced detailed. Because of the limit of paper, we take confining pressure is 2MPa and 6MPa as an example to introduce detailedly.

As can be seen in Fig.2, as confining pressure is 2Mpa, the main shock is produced in the 32nd step, obvious microseism precursory is produced in the29th step, so we can use microseism precursory information which is before the main shock namely the 29th~31th step microseism precursory information to predict the location or range of potential damage danger area.

Fig.3 is the numerical simulation results of microseism activity space distribution when confining pressure is 2Mpa. In the figure each circle represents a microseism position, the red circle shows that the microseism event is produced by the tension stress effect, the white circle shows that the microseism event is produced by the compression stress effect, the circle diameter represents the energy which the microseism releases.

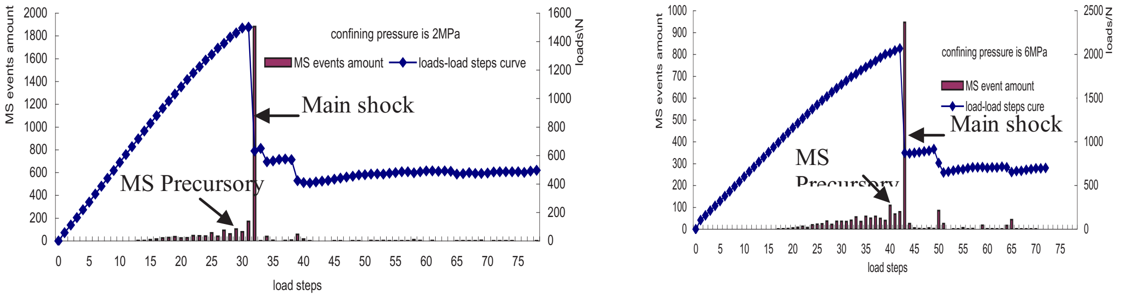
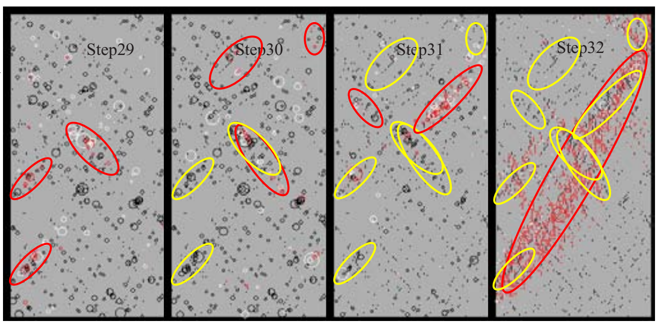


Fig.2 MS accounts, load and Load steps curves in different confining pressure

Through all the simulation samples microseism activity space distribution characteristics, it is can be found that in the previous stage of microseism event, there is mainly induced by compression stress, in this time macroscopic failure doesn't occur in the sample, in the middle and later stage there exist many microseism events which are induced by tension stress. When the main shock occurs, the microseism events in the failure area are mainly produced by tension stress. At the same time, according to the compression resistance and non-tension resistance character of coal, it is can be considered that the space distribution of microseism event which is produced by tension stress has high consistency with the sample potential damage danger area. Basing on this idea, its division result can be showed in Fig.3. The red ellipse expresses the potential damage danger area divided based on current step microseism event which is produced by the tension stress, the yellow ellipse expresses the potential damage danger area divided based on pre-current step microseism event which is produced by the tension stress. Through the 32nd step (main shock) division result, it is can be found that the potential damage danger area which is divided by using microseism precursor information is mainly contained in main failure area or surrounding, only a few potential damage danger area away from it. It is clear that division result of potential damage danger area is more accurate. Fig.4 is process of crack initiation, comparing Fig.3 with Fig.4, it is can be found that potential damage danger area which is obtained by predicting is the area where crack initiation occurs.



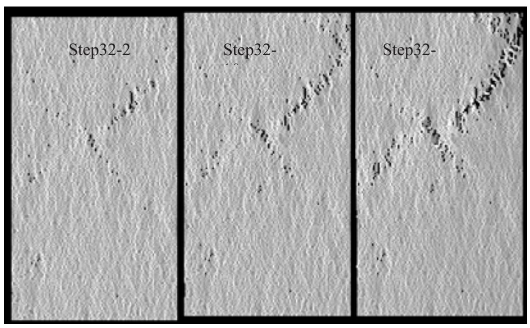


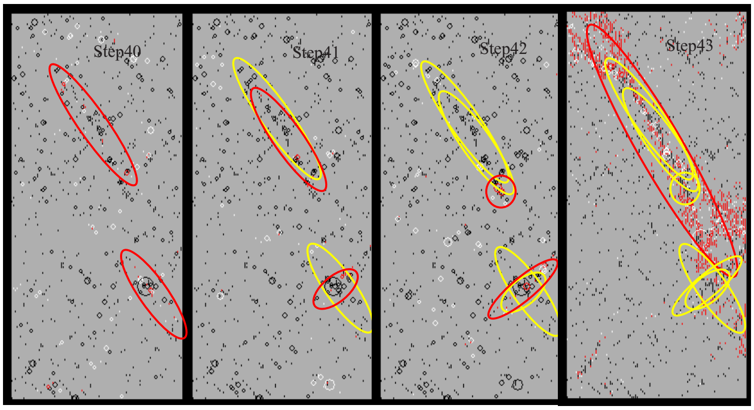
Fig.3 Process of used MS auspice forecast in 2MPa confining pressure

Fig.4 Process of crack initiatory in 2MPa confining pressure

As can be seen in Fig.2, when confining pressure is 6Mpa, the main shock is produced in the 43rd step, obvious microseism precursor is produced in the 40th step, so we can use microseism precursor information which is before the main shock namely the 40th~42th step microseism precursor information to predict coal potential damage danger area. Its division result can be showed in Fig.5. Through the 43rd step (main shock) division result, it is can be found that the potential damage danger area which is divided by using microseism precursor information is mainly contained in main failure area or surrounding. It is clear that division result of potential damage danger area is more accurate. Fig.6 is process of crack initiation, comparing Fig.5 with Fig.6, it is can be found that potential damage danger area which is obtained by predicting is the area where crack initiation occurs.

Through the results of confining pressure is 2MPa and 6MPa respectively, it is can be found that the accuracy of partition of potential damage danger area is high. So the method of partition of potential damage danger area is available.

It is found that when confining pressure is 2MPa the amount of partition of potential damage danger area is bigger than that when confining pressure is 6MPa, and the accuracy of partition of potential damage danger area is lower than that when confining pressure is 6MPa. The reasons for this is that when confining pressure is 2MPa, the ability of resisting destroy is weaker for units of gassy coal sample, thus it induces failure of units of gassy coal sample, produces a lot of microseism precursory events, and it decreases the accuracy of partition of potential damage danger area. When the confining pressure is 6MPa, the ability of resisting destroy of units of gassy coal sample is enhanced, the amount of microseism precursory events is decreased, so the accuracy of partition of potential damage danger area is high.



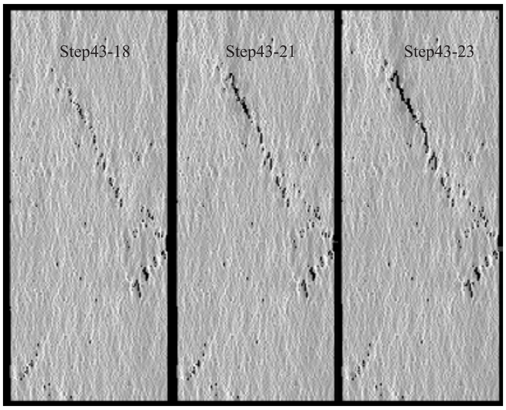


Fig.5 Process of used MS auspice forecast in 6MPa confining pressure

Fig.6 Process of crack initiatory in 6MPa confining pressure

3 Conclusions

As main shock occurred, coal samples produce macroscopic unstable failure. Before main shock, namely before macroscopic unstable failure, there are some microseism precursor information. It is can be warned in advance for macroscopic failure of gassy coal sample basing on the distribution characteristics of microseism precursor in time (step). According to the distribution of microseism precursory events produced by tension stress in space there is can predict the initial failure location of gassy coal sample. With the increment of confining pressure, the accuracy of partition of potential damage danger area is become higher. It is found that the potential failure danger zone consistent with crack initiatory zone by contrasted potential failure danger zone to crack development process, and with the increment of confining pressure, the consistency is become higher. So adopted protection measures to potential danger area, the occurring of instability failure can be prevented.

The research results provide a theoretical reference for the microseism monitor technology being applied in coal and gas outburst, but there are a lot of problems still need be further studied, such as the influence of heterogeneity for the distribution characteristics of microseism precursory and so on.

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