Experimental of mechanical properties and gas flow of containing-gas coal under different unloading speeds of confining pressure

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Abstract

Based on self-developed “Triaxial Stress Thermal-hydrological-mechanical Coal Gas Permeameter”, the experiment of the influence of different unloading speeds on mechanism and gas seepage features of containing gas coal is carried out, with the condition of initial confining pressure 6MPa and gas pressure 1.0MPa. It shows that: with the increasing of unloading speed of confining pressure, the time of coal maintaining at a stress plateau phase reduces, and it tends to 0, and the easier coal is to be fail After the start of unloading confining pressure, the time of coal maintaining in the stage of stress plateau showed a power function relation with unloading speed of confining pressure. In this study, the speed can be classified into three regions in text: the low speed region of unload confining pressure, the intermediate speed region and the high speed region. In the three speed regions, the confining pressure, when coal fails, is lowest in the low unloading speed of confining pressure, middle in the intermediate unloading speed region, and highest in the high unloading speed region.

Keywords: mining engineering; unloading speed of confining pressure; permeability; gas; stress-strain

1. Introduction

In the process of underground coal exploiting, coal will continuously strip out from the wall with the coal work face goes. This process changes the stress state of coal body which is in the mining sphere of...
influence and has not been stripped out[1]. That is to say confining pressure is gradually dropped [2]. Unloading conditions make it easier for coal unstable failure occurred[3]. Therefore, the research of the coal nature under the conditions of unloading confining pressure provides a theoretical basis for the safety mining of underground mine. In terms of research of the coal nature under the conditions of unloading confining pressure, Su Chengdong etc.[4,5] and Huang Qixiang etc.[6] studied the deformation and strength characteristics of coal without gas under the conditions of unloading confining pressure, Su Chengdong etc.[5] and Liu Baoxian[7] studied the sound emission characteristics of coal without gas under the conditions of unloading confining pressure, Zhao Hongbao etc.[2] studied the evolution of mechanical properties of containing-gas coal under the conditions of unloading confining pressure, Yin Guangzhi etc.[3] and Jiang Changbao etc.[8] studied the mechanical properties and gas flow features of containing-gas coal under the conditions of unloading confining pressure. Yin Guangzhi etc.[3] researched influence of mechanical properties and gas flow of containing-gas coal under unloading speeds of confining pressures, but the unloading speed of confining pressure was relatively low. In fact, the different feed sizes of the coal cutter and the different advancing speeds of the coal work face cause the different effects of unloading confining pressure. It is worthy of further study for us to research the influence of mechanical properties and gas flow of containing-gas coal under high unloading speed of confining pressure. Therefore, based on the study of Yin Guangzhi etc.[3], the further research of the influence of mechanical properties and gas flow of containing-gas coal under high unloading speed of confining pressure is evolved in this article.

Nomenclature

\[\begin{align*}
\sigma_1 & \quad \text{axial stress} \\
\sigma_3 & \quad \text{confining pressure} \\
\varepsilon_1 & \quad \text{axial strain} \\
\varepsilon_3 & \quad \text{transverse strain} \\
\varepsilon_v & \quad \text{volumetric strain} \\
K & \quad \text{permeability} \\
T_i & \quad \text{the time of the coal being in the stage of stress flat roof} \\
v & \quad \text{the unloading speed of confining pressure}
\end{align*}\]

2. Test Overview

This test assumes Chongqing University self-developed “Triaxial Stress Thermal-hydrological-mechanical Coal Gas Permeameter”. The test coal samples derive from 7th coal seam of Datong in Chongqing Songzao Coal Co., Ltd which are same with coal samples of article[3]. The test program is generally same with article[3], the increase is the experiment that the initial conditions is that confining pressure is 6MPa and gas pressure is 1.0MPa, unloading speeds of confining pressures are 0.022 MPa/s, 0.026 MPa/s, 0.030 MPa/s, 0.034 MPa/s, 0.038 MPa/s, 0.042 MPa/s, 0.046 MPa/s, 0.050 MPa/s, 0.052 MPa/s, 0.054 MPa/s, 0.058 MPa/s.
3. Test results and analysis

Because the evolution law of stress, strain and permeability under 14 kinds of unloading speeds of confining pressures are same, therefore, we can take one of unloading speed confining pressure test results as typical of this series of test results, as shown in Figure 1.

As can be seen from Figure 1, the coal would first undergo a stage of stress plateau, after the unloading process began, and then a break would happen due to destabilization, it shows that coal can maintain a stability time in the early period of unloading process. Figure 1 also shows that after the start of unloading confining pressure, permeability of coal increases very quickly. Researching the time of the stress plateau phase after unloading confining pressure can predict the time of coal maintaining stability, then can systematically take the roadway support work in the period time of maintaining stability, in order to avoid the occurrence of the coal and gas outburst disasters.

Figure 2 shows the relation between unloading speed of confining pressure and time of coal stress plateau phase. As can be seen from the Figure, with the increasing of unloading speed of confining pressure, the time of coal maintaining at a stress plateau phase reduces, and it tends to 0, it shows that after unloading speed of confining pressure reaches a certain speed, coal occurs unstable failure at the moment of beginning unloading confining pressure. It shows that it is prone to come about coal and gas outburst disasters when the speed of excavation at the coal achieves a certain extent. After analyzing the reason, it is considered that under the conditions of the same initial confining pressure, after the same time of starting unloading confining pressure, the faster unloading speed of confining pressure is, the lower confining pressure of the coal under high speed unloading confining pressure is. The higher the confining pressure is, the greater the strength of coal is. Therefore, coal quickly destroyed which is under the conditions of high unloading speed of confining pressure. Fitting the test results, the relation between unloading speed of confining pressure and the time of coal maintaining in the stage of stress plateau is fitted as:

$$ T = 0.0502v^{-1.745}(R^2 = 0.7185) $$

The common relation between the unloading speed of confining pressure and the time of coal maintaining in the stage of stress plateau is deduced as:

$$ T = av^b $$

Where $T_i$ is the time of coal maintaining in the stage of stress plateau(s), where $v$ is the unloading speed of confining pressure(MPa/s), where a and b are fitting constant, what’s more, $a>0$, $b<0$. 

![Figure 1 The typical relation curves of stress-strain and permeability-strain](image-url)
In the coal mining site the original ground stress, gas pressure and the excavation speed of coal seam can be measured, researching the time of the stress plateau phase after unloading confining pressure can predict the time of coal maintaining stability by using relation (1), then can systematically take the roadway support work in the period time of maintaining stability, in order to avoid the occurrence of the coal and gas outburst disasters.

\[ T_t = 0.0502v^{-1.745} \]

\[ R^2 = 0.7185 \]

Figure 2 Relationships between the time of the coal being in the stage of stress flat roof and the unloading speed of confining pressure and their fitting curves during the unloading confining pressures

Figure 3 Relationships between The unloading speed of confining pressure and confining pressure of coal failed

Figure 3 shows the relation between the speeds of unloading confining pressure and the confining pressure when coal failed. It can be obtained that with different speed, the confining pressure differs sharply. The speed can be classified into three regions in text: the low speed region of unload confining pressure, 0.004MPa/s~0.008MPa/s; the intermediate speed region, 0.022MPa/s~0.050MPa/s; and the high speed region, 0.052MPa/s~0.058MPa/s. Coal fails as the unloading of confining pressure is at 3.9MPa~4.3MPa in the low speed region, and in the intermediate speed region, it is 4.5MPa~5.4MPa, while in the high speed region it will be 5.9MPa~6.0MPa. Obviously, the confining pressure, when coal fails, is lowest in the low unloading speed of confining pressure, middle in the intermediate unloading speed region, and highest in the high unloading speed region. For the high unloading speed of confining pressure region, coal fails even in the first time of unloading confining pressure. The reasonable explication is that: unloading confining pressure has a shock effect on coal. With the increase of the speed of unloading confining pressure, the shock effect becomes greater. So in the condition of unloading confining pressure, it appears that the confining pressure, when coal failing, has an increase at the stages state with the speed of unloading confining pressure increases. What’s more, when the speed reaches a certain value, coal will fail just at the flash of unloading confining pressure starting.

From what’s analyzed above, coal mining should be going on at the stage of intermediate speed region of unloading confining pressure in coal face so that ensure the advancing progress of coal face and have enough time to support the entry ways for the coal-mining safety and efficiency.

4. Conclusions

(1) The following results can be drawn. The greater unloading speed of confining pressure is, the shorter the time of coal maintaining at a stress plateau phase is, and it tends to 0, the more prone coal
unstable failure can be. After the start of unloading confining pressure, the time of coal maintaining in the stage of stress plateau showed an power function relation with unloading speed of confining pressure.

(2) In this study, the speed can be classified into three regions in text: the low speed region of unload confining pressure, the intermediate speed region and the high speed region. In the three speed regions, the confining pressure, when coal fails, is lowest in the low unloading speed of confining pressure, middle in the intermediate unloading speed region, and highest in the high unloading speed region.

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