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Creep properties and a creep equation of delay outburst coal and its adjacent mudstone

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ABSTRACT

The study of the creep properties of coal and its adjacent mudstone is very important for understanding the mechanism of delay outburst coal. The samples of delay outburst coal and its adjacent mudstone collected from Yongshanqiao mine were used to carry out triaxial creep tests. The influence of confining pressure and axial compression on the creep test was analyzed. An accelerated creep model was constructed in parallel with a nonlinear viscous component and plastic component. It is connected with the traditional Burges creep model in series. A creep model which can describe the nonlinear visco-elastic-plastic creep model of rock was established and the corresponding creep equation was derived. According to the results of the creep test, the related parameters of the equation were fitted. The results show that, under the same confining pressure, instantaneous creep strain, creep strain of deceleration phase and constant rate creep of the coal and its adjacent mudstone are increased with an increase in the deviatoric stress. But at the same axial pressure, all of the above decrease with an increase of confining pressure. The duration time of the deceleration creep phase increases with the increase in the deviatoric stress. The theoretical values of the creep equation are in good agreement with the experimental results. It indicates that the creep properties of the delayed outburst coal and its adjacent mudstone can be well described by the creep model established in this paper.

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1. Introduction

Coalbed methane is not only a resource, but also could be a disaster in a coal mine. Promoting the favorable and avoiding the unfavorable is the effort direction of research. At present, research on coal and gas outbursts remains at the hypothesis stage [1–3]. Delay outburst is one of the phenomenon of coal and gas outburst. Generally, it occurs a few hours lag after mining blasting [4] and has the property of time-delay and concealment. It may also occur in working time and workers may have no time to protect themselves, resulting in more serious loss. Therefore, delay outburst must be paid higher attention.

Research into delay outburst of coal and gas has received little attention in both domestic and foreign research programs. The mechanism of occurrence is not clear. The prediction and prevention of delay outburst in mining sites has lacked the necessary impetus. In recent years, some scholars have realized that delay outburst was often related to the creep properties of coal [5]. Creep test apparatus for containing gas coal rock was used to conduct much experimental research into the creep characteristics of coal, which was developed by Yin, Wang, Zhang and many other scholars. The effect of gas pressure, confining pressure, axial pressure etc. on the creep properties of containing gas coal were accessed. A creep constitutive model suitable for describing the outburst seam was proposed [6–12]. The above research results have enriched the theory of coal creep, and laid the foundation for the application of creep theory to reveal the mechanism of coal and gas delay outburst. But the early results were often aimed at the study of the creep properties of the coal itself, and the creep property of the adjacent layers of the delay outburst coal was of less concern.

It was well known that the original stress balance of surrounding rock (coal), caused by roadway excavation, is destroyed, and that some of the stress is released in the initial stage whilst the follow-up stress is released slowly with the passage of time. At the same time, with the decrease in pressure on one side of the roadway, gas migrates to the surrounding roadway. When the gas migration channel is not sluggish, the high gas pressure can be gathered together. When it reaches a certain degree, the surrounding rock (coal) cannot withstand the pressure, and energy is released instantly and delay outburst of coal and gas occurs

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[5]. For instance, before the formation of the Shimen cross cut, due to the creep characteristics of the coal seam and its adjacent mudstone, the influence of excavation stress adjustment and the gas pressure might lead to delay outburst of the coal and gas (as shown in Fig. 1). Therefore, delay outburst of coal and gas is related to the creep properties of coal and its adjacent layers of mudstone from the perspective of the mechanics of the medium.

In order to study the creep characteristics of coal and its adjacent layers of mudstone, the outburst-prone coal seam and its adjacent mudstone of Yongshanqiao mine in Jingdezhen City, Jiangxi Province were selected as the research object. The triaxial creep test was conducted to study the creep characteristic curve of coal and its adjacent mudstone under conditions of different confining pressure and different creep load. Its creep properties were also analyzed. On the basis of the above, paralleling the nonlinear viscous component with the plastic components, and then cascading with the traditional Burges model, a creep model which can describe the non-linear visco-elastic-plastic characteristics of soft rock was established, and the corresponding creep equation was derived and the relevant parameters of the equation were fitted. The research results provide a reference for revealing the mechanism of coal and gas delay outburst from the perspective of creep.

2. Test scheme

2.1. Test apparatus

The triaxial test and creep test of the coal and its adjacent mudstone were carried out on the W3Z-200 test machine developed by Anhui University of Science and Technology (as shown in Fig. 2). The main working principle of the test system included 3 major test systems: a loading system, a computer automatic data acquisition system and a control system. During the testing process, the automatic system collected and stored data on load, displacement, deformation, confining pressure and the wave shape which changed with time, which provided a reliable basis for the study of the triaxial mechanical properties of the coal and adjacent mudstone samples.

2.2. Specimen preparation

Delay outburst coal and adjacent mudstone of specimen making were collected from Yongshanqiao mine, Jingdezhen City, Jiangxi Province. The delay outburst coal samples were a soft coal of 14.3 kg and an adjacent mudstone of 12.5 kg. The soft coal presented as flake, powder and small mirror sheets. Mudstone presented as massive unicorn horn shapes.

Due to the low strength of the collected coal and its adjacent mudstone, it was difficult to make standard triaxial samples, so a method which used the broken structure and then re-made samples was adopted. In the laboratory, standard cylindrical specimens with a diameter of 50 mm, height of 100 mm was made by using a

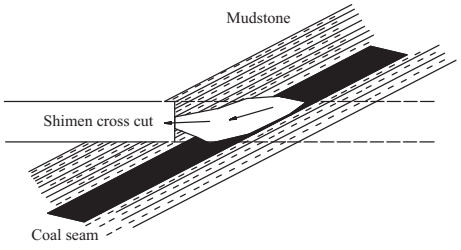

Fig. 1. Schematic view of coal and gas delay outburst.

Fig. 2. Triaxial creep instrument of W3Z-200 type.

production system for coal rock samples. The system mainly consisted of the hydraulic cylinder, hydraulic pump, pipe sink flow system, mould, hydraulic platform, pressure gauge, etc. The preparation process was: break the collected coal and rock bulk first, and then place in the cylinder, beat repeatedly making powder particles. The powder particles were then screened by using vibrating screen of 80-mesh. Coal powder and rock powder less than 178 μm in size were sieved out. Finally, coal rock powder and an adhesive were mixed in the appropriate proportion and placed in the hydraulic press for molding. 30 min of static set were allowed after reaching the pre-determined pressure. The sample was then removed. The parts of the prepared samples are shown in Fig. 3.

2.3. Test scheme

The creep test had a great relationship with the stress level, and if the stress was too small, it only had a slight creep deformation effect; otherwise, it would accelerate the occurrence of creep deformation and ensured failure. Therefore, to determine the axial loading level of the outburst coal and its adjacent mudstone in conditions of different confining pressures, it was necessary to carry out conventional triaxial tests under different confining pressures of σ_3. The characteristics of the stress-strain curves were thereby obtained. The shearing strength value $(\sigma_1 - \sigma_3)_{max}$ of the peak was also obtained which provided a reference for the axial loading level of the triaxial creep test at different confining pressures of σ_3. The scheme of the conventional triaxial test and triaxial creep test are shown in Table 1.

3. Conventional triaxial test

Triaxial tests were completed on a rigid servo testing machine. The pre-production specimens were selected and the selected specimens looked good in appearance with no obvious defects. The typical full stress-strain curves of the delay outburst coal and mudstone were obtained by employing a loading rate of 0.02 mm per second, until the specimen was destroyed. The curve

Fig. 3. Part of the standard sample.

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