International Journal of Mining Science and Technology 24 (2014) 637–641

Contents lists available at ScienceDirect

International Journal of Mining Science and Technology

journal homepage: www.elsevier.com/locate/ijmst

A method of determining the permeability coefficient of coal seam based on the permeability of loaded coal

Li Bo [a,b,c,*], Wei Jianping [a], Wang Kai [a,c], Li Peng [c], Wang Ke [a]

[a] State Key Lab Cultivation Base, Henan Province Key Lab of Gas Geology & Gas Control, Henan Polytechnic University, Jiaozuo 454003, China
[b] School of Materials Science and Engineering, Henan Polytechnic University, Jiaozuo 454003, China
[c] School of Resources & Safety Engineering, China University of Mining & Technology, Beijing 100083, China

ARTICLE INFO

Article history:
Received 2 November 2013
Received in revised form 5 February 2014
Accepted 15 April 2014
Available online 19 August 2014

Keywords:
Permeability coefficient
Coal seam
Effective pressure
Loaded coal
Pore pressure

ABSTRACT

This study developed the equipment for thermo-fluid–solid coupling of methane-containing coal, and investigated the seepage character of loaded coal under different working conditions. Regarding the effective pressure as a variable, the variation characteristics of the gas permeability of loaded methane-containing coal has been studied under the conditions of different confining pressures and pore pressures. The qualitative and quantitative relationship between effective stress and permeability of loaded methane-containing coal has been established, considering the adsorption of deformation, amount of pore gas compression and temperature variation. The results show that the permeability of coal samples decreases along with the increasing effective stress. Based on the Darcy law, the correlation equation between the effective stress and permeability coefficient of coal seam has been established by combining the permeability coefficient of loaded coal and effective stress. On the basis of experimental data, this equation is used for calculation, and the results are in accordance with the measured gas permeability coefficient of coal seam. In conclusion, this method can be accurate and convenient to determine the gas permeability coefficient of coal seam, and provide evidence for forecasting that of the deep coal seam.

1. Introduction

The permeability coefficient of gas indicates not only the difficulty of gas flow in coal seam, but also the outburst hazard of coal and gas and the feasibility of gas extraction. In order to provide accurate technical parameters for mine design and gas prevention which ensures the mine safety production, the change of coal seam permeability should be well-known. At present, the permeability coefficient of coal seam can be determined by laboratory test and/or field measurement. Laboratory measurement method is relatively simple with low costs of manpower, material resources and time, but it usually exhibits big difference with the real value. It is mainly due to the lack of the fissure of coal during the preparation process of particle coal samples in laboratory, and the coal seam permeability coefficient caused cannot be truly reflected. For the field measurement, it mainly adopts in-situ test method on the basis of radial unsteady flow theory. Although the actual situation on site can be better reflected by this way, it costs a lot of manpower and material resources. Additionally, due to the poor permeability in our country, the inaccurate results would be obtained if the change of drilling flow rate cannot be accurately determined with the big borehole flow attenuation coefficient after discharging a quantity of gas from pressure drilling.

A lot of studies on the gas permeability coefficient have been reported at home and abroad. The Marconi pressure method known as the secondary pressure method has been reported [1]. Its advantages lie in the simple testing work, short time and the small computing workload, but it considers that only the free gas in coal seam participates in the flow which contradicts that the gas is mainly adsorbed in coal seam. The Klinefelter pressure method known as the single pressure method has been reported, but the influence on the gas pressure rise curve by the amount of discharged methane has not been taken into consideration during the period from completing drilling to hole sealing [2]. The time factor is also eliminated in the gas source radius formula for calculation.

The foundation for determining the permeability coefficient has been established by the proposed radial flow methods [1,3]. The borehole radial flow method has been widely used in our country owing to its precise measurement results, practicality and less limitations from the conditions of coal seam, although this test method is complicated. The relationship between *AB* and time numeral F_0 during the determination of coal seam permeability

* Corresponding author. Tel.: +86 13839117169.
E-mail address: anquanlibo@163.com (B. Li).

http://dx.doi.org/10.1016/j.ijmst.2014.04.002
2095-2686/© 2014 Published by Elsevier B.V. on behalf of China University of Mining & Technology.

coefficient is analysed by borehole radial flow method, and the optimisation of calculation method for permeability coefficient is proposed [4]. A new method for determining the gas permeability coefficient of coal seams has been developed by using the infiltration rate of particle coal [5]. However, it is inconsistent with the actual conditions due to lack of the consideration of coal samples under load.

The study investigated the influence of the secondary stress of coal and the gas pressure around drill on the permeability coefficient of coal seam, and found that the permeability coefficient of coal gas decreased with increasing distance [6]. To enhance the permeability coefficient of gas, the means such as water pressure blasting crack, loosening blasting, hydraulic flushing and mining protective layer is also studied [7–11]. Those studies mainly aimed at optimising the calculation method and improving the permeability coefficient of coal seam, while it needs to measure the gas pressure of coal seam and the gas flow of drilling in field. This determination process is complicated with a long cycle, so it is difficult to be widely applied in the mines without pressure measurement conditions.

This study utilised the self-developed equipment for thermo-fluid–solid coupling of methane-containing coal, and analysed the feature change of the permeability of loaded gas-containing coal. Then, the qualitative and quantitative relationship between coal permeability and effective pressure was established based on the experimental results. Finally, a new method for determining the gas permeability coefficient of coal seams was proposed with the permeability of loaded coal, which provides the theoretical basis and prediction of the permeability of deep coal seam.

2. Test of seepage properties of gas-containing coal

2.1. Experimental system

With the self-developed equipment for thermo-fluid–solid coupling of methane-containing coal, the gas permeation of coal sample test can be simulated under different crustal stresses (i.e., confining pressure and axle load) and pore pressure. As shown in Fig. 1, this device consists of the loading system, triaxial cell, pore pressure control systems, data measurement system and temperature control system. It can meet the combination test with different confining pressures, axle loads and pore pressures, ensuring a good sealing function. The load is provided by the hydraulic pump. The pore pressure control system consists of the gas bottle, reducing valve and pipeline, in which the gas bottle supplies CH_4 with a purity of 99.999% and the reducing valve adjusts the gas pressure of air inlet. The measuring system consists of the stress acquisition system, the displacement acquisition system, the gas mass flowmeter and the strain collect checkout gear. To ensure the accuracy and reliability of data, the whole experimental process was conducted on the operating table and controlled by computer program, including the record of data acquisition.

2.2. Experimental process

Considering the effect of confining pressure, the effective stress is used as a variation to study the coal permeability by changing the confining pressure and axial compression. Based on the experimental results, the qualitative and quantitative relationship between loaded coal permeability and effective stress is established.

The experiments can be divided into two parts:

(1) The triaxial loading penetration was studied with the pore pressure of 0.6, 0.9, 1.2 and 1.5 MPa and the confining pressure of 1, 2, 3 and 4 MPa, respectively. First, the seaming chuck was pressed to push down the sample until the confining pressure increased to a predetermined value. In order to avoid the influence of impurity gas in coal, the entire system was vacuum degassed to be vacuum state, then the methane was filled into the system and the penetration test was carried out under this pressure condition. Thus the pore pressure was adjusted to study its influence on the coal permeability under different loading conditions. After increasing the confining pressure to larger load, the pore pressure was changed according to the test sequence which is used to simulate the coal loading stress conditions. To confirm the influence of effective stress on the coal seam permeability at different loading stages, the same experimental procedure was repeated.

(2) Through changing the confining pressure, the above experimental process was repeated to study the relationship between the permeability and effective stress under different effective stresses.

The process is described as below: (1) put the coal sample in the thermo-fluid–solid coupling equipment with the methane-containing coal, and check the air tightness and load the scheduled confining pressure and axle load; in order to avoid the affect of impurity gas, the entire system is vacuum degassed more than

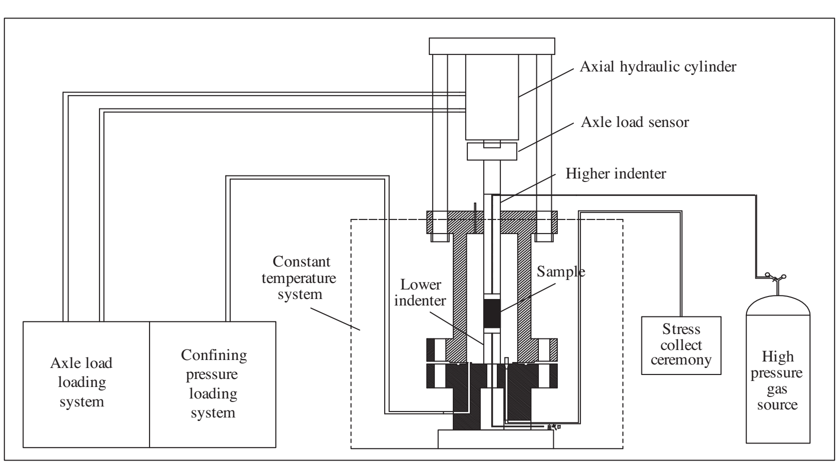

Fig. 1. Experiment system structure schematic diagram.