The 2018 World Congress on
Advances in Civil, Environmental, & Materials Research (ACEM18)
Songdo Convensia, Incheon, Korea, August 27 - 31, 2018

Study on Permeability-damage Evolution Model of Gas-filled Coal

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ABSTRACT

According to the definition of porosity and energy equilibrium principle, and fully considering the primary deformation caused by the expansion of gas adsorption, shrinkage of desorption of coal and the gas pressure of pore, a permeability-damage evolution model of gas-filled coal-rock considering effective stress was established based on the Weibull distribution theory of coal-rock strength and elastic energy released into coal-rock particles friction energy dissipation in the process of load failure process of coal-rock. According to the experimental data of triaxial stress test of gas-filled coal-rock, the theoretical model is verified. And the influencing parameters and their controlling mechanism of the permeability model have been comprehensively studied. The peak stress of coal is proportional to the parameter α. The decline rate of stress-strain curve after peak stress of coal is inversely proportional to the parameter m. As the n_0 increases, the peak stress of coal decreases, and the permeability evolution develops almost the same. As the σ_c increases, the strength of coal increase rapidly, and the permeability decrease first, then increases with the strain increases. The smaller the value of the parameter σ_c, the farther the stress value corresponding to the inflection point of permeability is to the peak value, and the rate of change in the penetration growth segment does not change much The research results have some guidance significance to the mine gas disaster prevention and drainage utilization.

Keywords: permeability; damage; evolution model; gas-filled coal; Weibull distribution

1. INTRODUCTION

Coal Bed Methane (CBM) is naturally occurring methane gas (CH_4) in coal seams. CBM is not only a kind of clean energy, but also a kind of greenhouse gas and a hazard to the coal mining. Its release during underground coal mining poses a significant threat to the environment and the mining safety (Chen 2012, Liu 2017). But now CBM is recognized as a valuable resource. Gas drainage is the most commonly used method

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*Note: Copied from the manuscript submitted to
"Geomechanics and Engineering, An International Journal" for the purpose of presentation at ACEM18/Structures18.

for gas disaster control and CBM recovery in coal mines (Noack 1998, Karacan 2011, Liu 2016, Zhou 2016). Besides, coal permeability is one of the most important factors affecting gas drainage in the process of the coal mining, which evaluation is affected by coal structure and gas adsorption/desorption (Danesh 2016, Connell 2010, Chen 2013, Wang 2016). Note that coal permeability can vary significantly during gas drainage in response to a decrease/increase in pore pressure and gas adsorption/desorption-induced coal matrix swelling/shrinkage. And with the gas drainage, the pore pressure will be changed and influence the coal matrix swelling stress and effective stress of the coal containing gas. Therefore, it is necessary to study the permeability evolution of coal seams and its controlling mechanisms.

Based on this assumption of coal structure, many models have evolved to represent the effects of sorption, swelling and effective stresses on the evolution of coal permeability over last few decades.

Palmer and Mansoori (Palmer 1998) built another widely used P&M model, which incorporated the effects of matrix shrinkage and effective stress. However, this model failed to match the field data from San Juan basin for the overestimated matrix compressibility (Liu 2013). An additional parameter (g) was then introduced to modify the model (Palmer 2007). Assuming that the change in cleat permeability was dominated by the effective stress normal to the cleats, Shi and Durucan (Shi 2005) developed a model (SD model) for pore pressure-dependent permeability. Cui and Bustin (Cui 2005) derived a stress-dependent permeability model (CB model) by quantifying the effects of reservoir pressure and volumetric strain caused by gas adsorption on coal seam permeability. Pan and Connell (Pan 2011) applied the anisotropic coal swelling model to the SD model to describe permeability behavior for primary and enhanced coalbed methane recovery. By applying the elasticity theory to the fractured rocks, Perera et al. (Perera 2013) modeled the relationship between permeability and gas-injecting pressure, confining pressure, axial load, and gas adsorption in triaxial tests. Lu (2012) analyzed the characteristic of permeability affected by stress level and porosity, studied the variable regularity of permeability of rock-mass during the complete stress-strain course, and proposed the characterization relation formula of permeability during the whole stress-strain course. Wu (2005) derived the calculation formulas on the swelling deformation of adsorption the swelling stress of adsorption and the effective stress in the adsorbed methane-coal system based on principles of surface physicochemistry and elastic mechanics. Li (2007) established an expressions of effective stress and swelling stress. And based on the expressions and the basic idea of fluid-solid coupling seepage theory, the mathematical model of fluid-solid coupled flow of coal-bed gas considering the swelling stress of adsorption