EDITORIAL

Role of thermodynamic effect on coal-gas interactions during underground pre- and post- mining coal seams in the environmental geology

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Underground coal mining generally occurs in the terrifically thermodynamic environment of high geostress and geotherm, resulting in many coal-gas disasters, such as coal-gas outburst, coal spontaneous combustion and even gas explosion etc. (1-3). Geological statistics and relative researches show that when mining depth is over 1000 m, the geotherm will reach the range of 40 and 45°C with the commonly geothermal gradient of 30-50°C/km, and the geostress is 95-135 MPa at 3500-5000 m depth (4). In addition, the geotherm has a significant impact on geomechanics of coal-rock mass: the variation of 1°C within the coal-rock medium may trigger the in-situ stress change of 0.4-0.5 MPa (5).

Coal-gas disasters pose a difficult, persistent and costly problem for coal industries worldwide, usually causing huge economic losses, personal casualties, perilous land subsidence and massive environmental contamination (6-10). The fundamental understanding of gas migration and coal self-heating is essential to eliminate their dangers as mining hazards or develop the potential as an unconventional gas resource recovered (11-14). The evolution of coal-gas interaction processes is a chain of physico-chemical reactions in underground pre- and post- mining coal seams, which is labeled as "coupled processes" implying that one reaction process affects the initiation and progress of another (15-17). This reaction chain is linked together through dominant mechanisms, including compositional gas flow and diffusion, reaction kinetics, energy transport and coal deformation (1,2,15). The individual reaction process, in the absence of full consideration of cross couplings, forms the basis of well-known disciplines such as hydrology, chemistry, elasticity and heat transfer (1,15).

Advances in our understanding of coal–gas interactions have provided some effective measures to retard or suppress underground coal-gas disasters and enhance potential resource utilization quality. Some typically mathematical models had been established to reveal coupled hydro-mechanical mechanism of coal seam gas flow, such as Palmer-Mansoori model (18), Shi-Durucan model (19), Zhang-Liu model (17) and Xia-Zhou model (20,21) etc., but failed to consider the influence of thermal effect on coal-gas interactions. However, in real coal mining environment, the thermodynamic effect may not only have a significant impact on the micro- and macro- structure evolution of coal-rock mass, but on gas ad/desorption, diffusion and migration behaviors. Thus, the thermodynamic effect should not be ignored in addressing the coal-gas interactions, which has become a kind of common recognition among many contemporary experts and scholars. Levy J et al. carried out an adsorption experiment of some coal sample, which showed that when the gas pressure of the coal sample was 5 MPa and the temperature was the range of 20 and 65°C, the adsorbed quantity of coal gas would be reduced by 0.12 m^3/t as the temperature increased by 1°C (22). Yin GZ, et al. experimentally studied the influence of thermal effect on the total stress-strain and gas flow characteristics of gaseous coals under the conditions of constant gas pressure and confining pressure (23). Based on the experimental study of the relationship among the permeability, temperature and stress, Li ZQ, et al. revealed that the relationship between the permeability and the temperature of coal sample was not monotone increasing or decreasing, but had a transition point under different effective stress (24). According to the permeability experiment of raw coal under the different temperatures and effective stresses, Xu J, et al. found that the larger the effective stress was, the less sensitive the thermal effect was (25). He MC, et al. and Wang CG, et al. implemented gas adsorption and seepage experiment under the uniaxial stress and heating conditions, which showed the thermodynamic effect had a significant impact on the mechanism of coal deformation, gas ab/desorption and migration (5,26). Peng SJ, et al. carried out the physical simulation test of gas extraction under different stress levels to study the evolution laws of coal temperature decline induced by gas desorption in extraction (27). Yang XL, et al. thought that the permeability of coal could be impressionable to some factors including effective stress, gas adsorption-induced microcalorimetry and coal temperature. Based on the experiment data, they further established a coupled hydro-mechanical model to address the characteristics of gas flow in coal seams (28). Taking the influence of thermodynamic effect on gas pressure, gas content, porosity and permeability into account. Li ZQ and Xian XF proposed a model of coal gas flow under the combined effects of the stress and temperature (29). Zhu et al. developed a coupled model of coal deformation, gas transport and thermal transport to examine the complex coal-gas interactions under variable temperatures (16). Considering the effects of gas pressure and gas desorption of coal. Tao YQ and Zhang LP established a coupled multi-physical model including temperature field, gas pressure field and coal deformation field Subsequently, they carried out different numerical simulations based on the enhanced gas recovery project of both energy and gas injections, respectively (30,31). In our latest work, my collaborators and I developed a series of coal-gas interaction models including hydro-mechanical models (20,21,32) and hydro-thermo-mechanical models (2,3,10,11,13), through combining some key physico-chemical reactions together, such as coal-rock deformation (gas-ad/desorption- and temperature-induced coal shrinking or swelling, and mining-induced coal-rock porosity evolution), methane diffusion from matrix, and compositional gas flow in fractures, coal-oxygen reaction kinetics, and thermal transport mechanisms, to further characterize gas migration or coal self-heating behaviors in underground coal seams or gobs.

Although a certain degree of success has been achieved using the above models and experiments to evaluate the coal gas or energy migration, control and recovery, the role of thermodynamic effect on coal-gas interactions during underground pre- and post- mining coal seams is not well understanding. This knowledge gap is likely to play a huge impact on coal-gas rick control and potential resource recovery. Thus, successful addressing the impact of thermodynamic effect on coal-gas interactions during underground pre- and post- mining coal seams will be serious scientific spotlights and challenges.

In this paper I have given a brief review of my research area associated with modern Environmental Geology. As we all known, unconventional coal resource and unconventional gas of shale and coal gas are causing a shift in the dynamics of the international energy structure, and there are a lot of similar issues and problems between coal and shale gas exploiting area. Because many scientific problems during unconventional gas and coal resource exploiting are closely related to multi-disciplines, including geoscience, rock mechanics, multi-component and multi-phase flow, geochemistry and thermodynamics

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etc., which is consistent with our theme of journal, I think that the journal "Environmental Geology" should give and be a great place to focus on this research area.

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