International Journal of Mining Science and Technology 27 (2017) 321–326

Contents lists available at ScienceDirect

International Journal of Mining Science and Technology

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

Some parameters of coal methane system that cause very slow release of methane from virgin coal beds (CBM)

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ARTICLE INFO

Article history:
Received 19 September 2015
Received in revised form 12 February 2016
Accepted 14 May 2016
Available online 30 January 2017

Keywords:
Coal bed methane
Porosity
Slow desorption
Diffusion
Virgin bed

ABSTRACT

In some worldwide hard coal basins recovery of methane from virgin coal beds is difficult. In general, mentioned difficulties are related to geo-mechanical, petrographical and physical-chemical properties of coals in question, occurring for example in the Bowen Basin (Australia) or the Upper Silesian Coal Basin (Poland). Among numerous properties and parameters, the following are very essential: susceptibility of coal beds to deformation connected with coal stress state change and contemporary shrinkage of the coal matrix during methane desorption. Those adverse geo-mechanical and physical-chemical effects are accompanied by essential change of the porous coal structure, which under these disadvantageous conditions is very complex. This study aims to show difficulties, which occur in phase of recognition of the methane-reach coal deposit. Volume absorbed methane (not surface adsorbed) in sub-micropores having minimal size comparable with gas molecule diameter must possess energy allowing separation of the nodes and methane release to micropores.

1. Introduction

In numerous European coal basins, and not only there, recovery of methane from virgin coal beds (CBM) for industrial scale is very difficult. Coal bed should be considered a specific gas collector with different properties from oil and gas collectors. The present study aims to explain the reasons why the bore-holes drilled down to virgin coal beds occurring in numerous coal basins are characterized with poor methane efficiency. Methane desorption rate is the most important parameter for efficiency of the methane recovery from this coal, including time of the reaching the level assuring expected gas output. Methane content in the coal bed, i.e. adsorption capacity in situ, is the other important parameter.

Coal bed considered as the methane collector should be tested with respect to geo-mechanical, petrographic and physical-chemical properties, because ability of methane release from virgin coal beds depends on various factors connected with these properties. Considerable amount of methane is trapped in fine micropores of the diameter lower than 1.2 nm and in sub-micropores of molecule size as a part of methane "dissolved" in coal matrix. This gas is considered as volume absorbed, contrary to the surface adsorbed methane in mesopores and macropores of the porous coal structure. Significant importance of coal structure, gas pressure as well as geo stress and strain during bed drilling for gas drainage was found in Ref. [1].

During methane drainage from the coal bed exposed to three axial stress state, the effective stress is increased in result of gas pressure drop. Dynamic stress state stimulates coal volumetric deformations accompanied with narrowing of all pores. However it is commonly known that methane desorption causes internal compression of the matrix, i.e. widening of pores. These two inverse effects have essential meaning for methane release from coal. The problem, which of these effects is dominant in chosen hard coal basins, has been described in this study. The Bowen Basin (Australia), San Juan (USA) and Upper Silesia Basin (Poland) have been described.

In some coal beds the methane is trapped in sub-micropores of molecular dimensions and it is strongly bounded with the matrix walls. In these structures the methane desorption, rather than via diffusion, is the slowest phase of methane transport in complex structure of the coal-methane system. Thus, if the gas is able to release from its volumetric original adsorption state, the methane will migrate via micropore network, and then it can be relocated via other part of the structure called microstructures e.g. micrometer-sized cavities. In the next phase gas filtration outflow via mezo-macropore network takes place [2].

Presence of mineral matter filling a part of this structure results from methane migration slowdown in macropores. Moreover

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http://dx.doi.org/10.1016/j.ijmst.2017.01.006
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important is whether pathways are open or not, of if they are frequently connected or not and what is their tortuosity.

In such circumstances, after period of fast desorption of the surface adsorbed methane, slow methane desorption via methane diffusion takes place. In commercial laboratories methane release rate and sorption capacity are commonly examined on prepared samples of crushed coal, or samples cut from coal lumps. In other laboratories, including those belonging to gas exploitation companies, observations of desorption rate and methane content with use of tight canister, in which core taken from bore hole is placed, are also executed.

Discussion presented in this study is predominantly based on results of examinations cited in available literature. Our attention will be focused first of all on qualitative aspect of differences between these results however quantitative data will also be presented. More detailed information about quantitative data can be found in references cited in the present study. Our attention was particularly focused on a question if high permeability of coal occurring in virgin coal beds what assures its effective exploitation-as is commonly considered in case of oil and gas deposits.

2. Effect of samples preparation procedure and its influence on methane sorption capacity assessment

2.1. Size of coal sample

Coal material separated from coal bed is partially destructed which considerably changes its properties. The coal-methane system is disturbed in result of change of physical and mical, geomechanical and structural conditions. Usually, three types of coal samples are used in laboratory examinations: samples of crushed fraction of coals, solid specimens cut from coal blocks and the drill cores taken from drilled coal beds. Thus the methane desorption with crushed samples takes place in completely different conditions than those occurring in situ, so in laboratory simulation of the stress state and strain state occurring in natural coal beds, is impossible. Crushing of coal would destroy the pore networks in coal matrix. It particularly concerns mesopores and macro-pores in case of coal grinding to fine fractions. Whereas, in result of coal crushing pore structure of coal is destroyed, because the internal surface area of crushed coal is bigger than in natural state. Moreover, when the large-pieces of coal samples are crushed to finer particles some of closed pores could be opened and it may result in the growth of the gas amount adsorbed in this laboratory conditions [3]. These circumstances create risk of ungrounded overstating of the sorption capacity in natural coal beds.

Unfortunately, the differences between sorption capacity obtained in laboratory experiment and real content of methane in natural coal bed, from which these samples were taken, can increase with decrease of the size of coal particles. It was proved by experimental examinations [4] that methane sorption capacity of larger grain size 0.50–0.70 mm was lower than methane sorption capacity of smaller grain size 0.088–0.125 mm of coal samples taken from the Zonguldak Basin (Turkey). The same trend of the influence of coal particle size on coal sorption capacity was confirmed by the results of other experimental examinations [5] with use of four different grain fractions of samples taken from the Upper Silesian Basin (Poland). Statement that the equilibrium of sorption state was achieved faster for samples of smaller grain-size and slower for coarse-grained samples has also been proved by examinations described in the present study.

Solid 1 g block samples crushed to fraction of 0.25 mm taken from the Bowen Basin (Australia) were also laboratory tested [6]. These examinations confirmed that crushed size sample reached equilibrium sorption state more quickly than solid samples.

It should be noted that change of coal particle size is accompanied by change of maceral content in coal [7] and studies executed in Aachen University (Germany), which were aimed at carbon dioxide storing (not cited in the present study).

2.2. Drying of coal samples

Coal occurring in natural beds is often water-saturated and properties of the wet coal are different than in case of dry coal. However, in laboratory examinations, in order to obtain comparable results with results obtained by other authors [8,9], drying of coal samples is made before starting the sorption measurements. It is commonly known that wet coal matrix sorbs smaller amount of methane than dry coal matrix. The linear decrease of methane sorption capacity with increasing moisture content in coals from the Bowen Basin (Australia) have been proved in laboratory studies [10]. Moreover, decrease of gas desorption rate with increasing moisture content in coal from the Upper Silesian Basin, as compared with dry coal, has also been proved [11]. Manner of drying of the samples is not meaningless as drying by exposing to air and heat alters coal structure [12]. In such conditions changes both coal porosity and permeability are possible. The thermal and microwave drying of low rank coals caused irreversible coal structure changes [13].

Thus we can conclude that use of dry coal samples in laboratory experiments generates some errors of the assessment of the characteristics of coal-methane system.

2.3. Mineral matter content in coal

In the coal composition, beside the maceral and water content, there are also other mineral matters present, which form compact crystalline or amorphous structures. These are diagenetic minerals such as quartz, carbonates and calcite partially infilling the microstructures and the macropores of coal matrix.

Mineral matter in coal, as expressed by its ash content, acts as a simple dilutent that decreases the amount of sorbable methane in the coal from the Bowen Basin, Australia [14]. In this work the proximate analysis and gas content results were recalculated so that only the organic fraction of different crushed samples of dry coal can be compared.

Similarly, to compare the petrographic composition with methane sorption capacity, samples from India coals are mineral matters free (ash free) [8]. The coal sorption capacity determined for mineral matter-free samples is too big and may generate some errors of the assessment of methane amount in coal beds.

In studies cited in this chapter one may find quantitative data referring to the influence of the grain-size, as well as water and mineral matter content onto coal sorption capacity.

It was also observed that in previous works, in which crushed coal samples or small solid samples and coal drying procedure have been applied, lack of mineral matter in coals was observed and rather coal geology problems were examined, whereas no attention was paid to the problem of full adequacy of this examinations with conditions occurring in situ during exploitation of the methane from virgin coal beds.

3. Degree of reservoir methane saturation

Degree of reservoir saturation is an important parameter of the coal-methane system. The following parameters are needed for its determination: value of gas content determined by canister desorption techniques, as well as methane sorption capacity of coal