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The application of the unipore and bidisperse models of methane sorption in hard coal

The subject of this dissertation is focused on the analysis and interpretation of the issues of sorption and transport of methane in the structure of hard coal. The analysis of the above phenomena helps to assess the level of the occurring natural hazards such as the threat of gas and rock outbursts. The use of unipore and bidisperse sorption/diffusion models enables the search for new safety evaluation criteria based on the coefficients found in their mathematical solutions. By studying the kinetics of gas accumulation and release from the coal structure, the information on the presence of gas in coal seams, and the possibility of its rapid outflow is provided. Peculiarly high diffusivity, as determined by sorption kinetics studies, is associated with zones of tectonic disturbance. When gas and rock outbursts occur, high diffusivity enhances the effectiveness of post-outburst mass transport. The kinetics of methane sorption processes in the hard coal structure depends on many factors. In particular, the internal structure is the key element affecting the rate of methane accumulation/release in hard coal.

The purpose of the presented dissertation was to assess the scope of application of the unipore and bidisperse models to gain knowledge regarding the sorption and diffusion kinetics of methane in a hard coal structure. The model time series were fitted to the measured kinetics of the sorption process on hard coal using unipore and bidisperse models. This allowed the determination of the corresponding coefficients found in the mathematical solutions that describe the rate of sorption/diffusion in coal. This knowledge helps to identify the characteristic altered coal structure, which may indicate the proximity of tectonic disturbances. It is important in the context of assessing the propensity of coal seams to the occurrence of gas and rock outbursts. For both models, an unknown set of parameters was sought, respectively: $\frac{D_e}{R_z^2}$, D_e – for the unipore model, and $\frac{D_a'}{R_a^2}$, $\frac{D_i'}{R_i^2}$, α, $\frac{\beta}{3\alpha}$ – for the bidisperse model. The above analysis has been performed regarding to changing petrography describing coal structure. Dependencies were presented, for which the application of a given model is possible, depending on the degree of coalification and maceral composition.

To achieve the dissertation objective laboratory tests related to sorption analysis and petrography for 23 coal samples collected from mines in the Upper Silesian Coal Basin in the years 2010 – 2021 have been conducted. The coals selected for the study were characterized by varying degrees of coalification and physicochemical parameters. In this work, microscopic studies were conducted to determine vitrinite reflectance and maceral composition. The sorption kinetics were determined using the gravimetric method. Mathematical modeling has been applied for the implementation of the unipore and bidisperse model to the real sorption kinetics time series and evaluation of the models' parameters. An appropriate identification procedure was developed using MATLAB software, based on minimizing the mean squared error (MSE) of the models relative to the experimental results.