

Abstract

This dissertation addresses the issue of the sorption process on hard coal with regard to gases released from the source of coal heating in the deposit. The findings presented in this study may have important practical implications for work safety in the coal mining industry. The process of gas sorption occurring in coal mine atmosphere during an endogenous fire has been frequently investigated and discussed in the field's literature. The studies demonstrated that carbon dioxide and acetylene are gases sorbed in the largest amount and that the extent of the adsorption of carbon monoxide and hydrogen is scant. However, most of the studies measured the adsorption of a single gas on coal or the mixture of carbon dioxide and methane as an adsorbant, and only in the context of enhanced coalbed methane recovery. Under real conditions, the gases emitted from the source of self-heating of coal constitute a multi-component mixture of gaseous products whose composition is characteristic of different temperatures of coal. The gap in literature concerning the flow and sorption of multicomponent gas mixtures on coal in the context of fire hazard in underground coal mining provides the rationale for the topic of this dissertation. The theoretical part of the study presents a description of the self-heating process of coal, the methods of fire detection in underground coal mines, as well as the issues related to the phenomenon of the sorption and transport of gases in the porous structure of coal.

The results of the study have been discussed in a series of 7 publications and constitute the main part of the dissertation. The aim of the research presented in these publications was to determine the sorption capacity of coals in relation to a multi-component gas mixture released during a simulated self-heating process of coal. The experimental tests were focused on the sorption of the following components of the mixture: ethane, propane, ethylene, propylene, acetylene, carbon monoxide, carbon dioxide and hydrogen. The assessment of fire hazard in underground coal mines is carried out based on the analysis of the trend of changes in the concentrations of the gases in the mine atmosphere and on the very value of fire indices calculated on the basis of their concentrations. Hard coals with various degrees of coalification collected from the main hard coal deposit in Poland, namely, the Upper Silesian Coal Basin were interchangeably used as the filling of the sorption column.

The results of the present study demonstrated that under real conditions the components of the gas mixture emitted from heated coal may be migrate through the coal bed at different rates and subject to sorption or desorption in various amounts.

A consequence of these phenomena is that the level of gas concentrations in control samples collected at stations of early detection of endogenous fire in relation to their values obtained in laboratory conditions may be overstated or understated due to the fact that the distance between the source of coal heating and gas sampling under laboratory conditions is shorter than in real conditions. The obtained high value of the Péclet number indicated that in the predetermined measuring conditions, on a macroscopic scale, the transport of gas in the mixture is determined by advection. A different flow velocity of the gaseous components of the mixture is caused by various reactivity of the gas molecules, varied content of the gases in the mixture and also by the physical and chemical properties of the coals.

Based on the results of this study, it can be concluded that propylene is the gas which is most sensitive to concentration changes in samples taken under real conditions. This gas reached the equilibrium state in the longest time and was sorbed in the larger amount in comparison to the remaining gases detected. The higher reactivity of propylene is related to the bond dissociation energy of the weakest C–H bond and the stability of the carbocation. Carbon monoxide and hydrogen had the shortest time of reaching the adsorption equilibrium. It was shown that the higher amount of sorbed saturated hydrocarbons in comparison to the unsaturated ones resulted from the several fold higher concentrations of ethane and propane in the mixture. It was also found that the impact of high adsorption of saturated hydrocarbons on the change in their concentrations in the control samples will be inconsiderable due to the fact that in the course of the study these gases reached equilibrium state in a short time. However, when the content of the saturated hydrocarbons in the mixture was only twofold higher than the concentration of unsaturated hydrocarbons, the amount of the sorbed component of the mixture was mainly determined by the chemical nature of coal and the high reactivity of the gas molecules.

The results obtained in the experimental part of this dissertation confirmed that the sorption capacity of the coals as regards the gaseous components in the mixture emitted during coal heating has an impact on the assessment of fire hazard in coal mines. The flow of fire gas mixture through the coal bed may lead both to competitive adsorption and a decrease in the permeability of coal resulting from the blocking of gas molecules in the narrow pores or from the swelling of the coal matrix. From the practical point of view, the longest retention time and high sorption of propylene on coal may be significant for the assessment of fire hazard based on the measurement of flammable gas concentrations. Therefore, the application of propylene as a fire indicator reveals justifiable limitations, which has been proven in the course of the experimental works.