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Influence of anti-pyrogenic materials on coal mining waste's tendency to self-ignite

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ABSTRACT

The aim of this work was to investigate the influence of anti-pyrogenic materials with use of Combustion By-Products (CBP) on the tendency of coal mining waste to self-ignite in laboratory conditions. The tested material sample was a mixture of coal waste with an addition of anti-pyrogenic material based on coal combustion by-products. The laboratory installation to test the properties of anti-pyrogenic materials is presented. The temperature of the tested sample as well as the concentration of carbon monoxide in exhaust gas were chosen as the parameters which determine the properties of anti-pyrogenic materials to reduce the self-heating process of coal waste. Laboratory tests of material samples were performed in a temperature range from 40 °C to 500 °C, at time interval of 350 s.

1. Introduction

One of the priorities for the currently applied technologies used in the disposal of mining waste is the minimization of endogenic fire occurrence. The essential elements for reducing risk of endogenic fire occurrence are: applying different kinds of anti-pyrogenic additions such as combustion by-products (CBP) or substances which are able to reduce self-heating phenomena (Cebulak, Gardocki, Miczajka, Szlosarek, & Tabor, 2010; Cebulak, Miczajka, Tabor, Skręt, & Gardocki, 2009; Gogola & Świnder, 2012; Zborszczik, Osokin, Rud, & Warakin, 1985; Łączny, Olszewski, Gogola, & Bajerski, 2011; Łączny et al., 2012). Anti-pyrogenic additions are generally the centre of attention in research papers and practical solutions concerning the prevention and countering of fire of coal mining waste dumps. The fundamental objective of anti-pyrogenic additions is the reduction of coal reactivity or the inhibition of combustion processes once they have already been initiated. The CBP are widely considered to be anti-pyrogenic materials. Burning dumps were covered with lime wash in the 1980s, in coal basins of the former USSR (Zborszczik et al., 1985). The addition of decarbonized limestone was also applied during the forming of the "Waleska" waste stockpile in Łaziska Górne (Korski, Friede, & Henslok, 2006). Cebulak et al. (2009, 2010) tested the effectiveness of calcium chloride and fire powders used for fire fighting in coal waste dumps in Rybnik. The research proved that applying calcium chloride and some tested fire extinguishing powders are suitable methods for fire prevention, especially at the early stage of heating the dump. Łączny and Ryszko (2012) tested the additions of anti-pyrogenic materials in the form of alkaline phenolic resins on a dump in Ruda Śląska. The result of the research was a patent of a series of compositions of mixtures for fighting fire of mine waste dumps (Łączny et al., 2010).

In most cases the selection and assessment of effectiveness of anti-pyrogenic materials were based on an analysis of its physicochemical properties, the assessment of the potential effects of its application and its testing when an object is on fire (Korski et al., 2006; Zborszczik et al., 1985; Łączny et al., 2012). Trials testing the influence of the anti-pyrogenic additives on coal mining waste's tendency to self-ignite in laboratory conditions were conducted through adaptation (without any modification) of methods in which anti-pyrogenic additions were tested on a relatively small sample mass of only coal (Cebulak et al., 2009, 2010).

The aim of tests was to investigate the influence of anti-pyrogenic materials, made up of combustion by-products, on the tendency of coal mining wastes to self-ignite in laboratory conditions. Previous experiments indicate that there is a need to develop an effective and repeatable research method which will serve an

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adequate assessment of the additives and admixtures in order to reduce the risk of the self-heating phenomenon.

2. Materials and methods

The research method determines the influence of temperature changes in the surroundings of the material sample. The tested material sample was a mixture of coal waste with the addition of CPB. The temperature change in the material sample leads to a sequence of physicochemical phenomena including gas stream emission, like carbon monoxide (CO), which allows a conclusion to be made about the capability of the material to self-ignite (Bystroń & Urbański, 1975).

Initial preparation of the samples consisted in their drying at 105 °C and further grinding into granulations of <0.2 mm. During the experiment the following were analysed continuously:

- changes of temperature in the tubular reactor (measurement with the use of thermocouple in the axis of material sample),
- changes of carbon monoxide concentration in gases at the reactor outlet (measurement with the use of a Madur GA-40 gas meter).

The conditions of the samples heating were identical, from the moment of placing the sample in the reactor tube the temperature increased from approximately 40-500 °C. The rate of heating was 50 °C/min.

Fig. 1 presents the laboratory installation for the testing of the tendency of the tested materials to self-ignite. The installation consists of the following elements: air supply system (1), reactor with a solid waste (2), heating system with the use of a resistance furnace (3), analyser of the reactor exhaust gas composition (4), system of measuring the temperature of the material sample (5, 6).

The measurement of the values of the parameters of the tested material was carried out according to the following measurement route:

- measurement of changes in internal temperature of the tested material using a system of thermocouples connected with a DTM-307 thermometer with an accuracy of ±1 °C (Fig. 1-(2)),
- measurement of carbon monoxide concentration in process gases by a Madur GA-40plus analyser with an accuracy of ±0.001% (vol%) (Fig. 1-(4)).

Conditions occurring during the experiment (placing the sample in a tubular reactor inside the furnace and the physicochemical reactions that occur) reflect, to a considerable degree, the conditions in the objects formed from coal mine waste which is on fire. When these type of objects are studied, the following conditions must be dealt with: the flow of thermal energy from places of self-heating initiation (*hot spots*) to the neighbouring areas, accumulation of energy in dumps and emission of gases which are the products of the chemical reactions. Commonly, in the course of testing the thermal condition of the objects formed from coal mine waste, carbon monoxide is recognized as a gas indicating progress of the combustion process.

Two samples of the materials were prepared for testing and these were labelled 01 and 02. A sample of coal mining waste was applied as a comparative material sample.

The material 01 constitutes a mixture consisting of burnt lime, aggregates and mineral binders, from the energetic use of mining fuels, in two granular fractions:

- dusty (0.01–0.1 mm),
- sandy (0.1–2 mm) and gravel (>2 mm),

and from aggregates, produced based on the composition of mining waste, in two granular fractions:

- 0–2 mm,
- 0–40 mm.

The material 02 constitutes a mixture of waste from a power plant and from selected mining wastes from coal processing and separation of underground waters, containing not more than 10% of inflammable parts, and also from waste which is made up of calcium carbide residue that does not contain dangerous substances.

The chemical composition is presented in Table 1. Table 2 lists the trace elements content in the analysed anti-pyrogenic materials. The chemical composition of the coal waste is shown in Table 3.

3. Results

The values of changes of the selected parameters that directly determine the tendency to self-ignite such as changes of temperature and carbon monoxide in the function of time are shown in Figures below which were measured in test conditions with use of the laboratory installation shown in Fig. 1. The temperature changes in time interval of 350 s is shown in Fig. 2. The characteristics changes of carbon monoxide at the outlet of reactor in time interval of 350 s is shown in Fig. 3.

The characteristic temperature and the carbon monoxide change for the tested materials 01 and 02 were compared with the coal waste. The maximum temperature and concentration of CO for sample 01 was achieved at the temperature of 221 °C and carbon

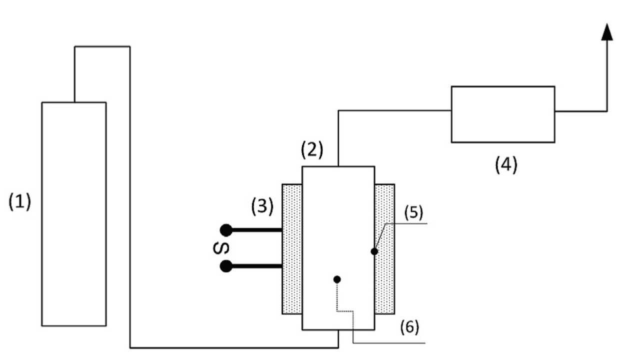

Fig. 1. The diagram of the laboratory installation with a reactor for testing the tendency of coal mine waste to self-ignite: 1 – air supplying system, 2 – reactor, 3 – resistance furnace, 4 – gas analyser, 5, 6 – thermocouplas.

Table 1
Chemical composition of the materials 01 and 02.

Component	Anti-pyrogenic material 01	Anti-pyrogenic material 02
	[wt%]	
SiO_2	44.58	45.66
Al_2O_3	21.57	19.12
CaO	6.03	4.80
SO_3	0.65	0.68
Fe_2O_3	6.78	6.37
MgO	1.91	1.48
Na_2O	0.77	0.56
K_2O	2.53	2.23
P_2O_5	0.20	0.14
TiO_2	0.94	0.83
loss on ignition	14.29	17.44