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Experimental study of coal dust deposition in mine workings with the use of empirical models

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ABSTRACT

Empirical models, developed on the basis of the results of tests on dust deposition and changes in concentration of dust in the protective zone, are the proposed tools to reduce risk of coal dust explosion. The paper presents possible applications of such models to assess and monitor volume of dust in a protective zone. Underground tests were conducted in the tailgate and headgate of longwall 121 of Brzeszcze Coal Mine. Basing on the analysis, the empirical models describing relationship between changes in dust concentration, and dust deposition in a protective zone of roadways: headgate and tailgate of longwall 121 in Brzeszcze Coal Mine, were developed. The developed models show a possibility of predicting explosive dust deposition in a protective zone. After additional research is run, it is planned to generalise the developed empirical model, which will enable monitoring of protective zones.

1. Introduction

Construction of protective zone (at least 200 m of mine working) to prevent propagation of explosions is an obligation imposed on coal mines, which excavate coal in mine workings of class A or class B of coal dust explosion hazard (Cybulski, 2004, Du, Huang, Kuai, Yuan, & Li, 2012). Mine workings located in protective zones must be washed with water or stone dusted (Amyotte, 2006) at a length of at least 200 m from a possible source of explosion (Cybulski, 2004). The above-mentioned actions are effective provided that the protective zone is duly maintained (Cybulski & Malich, 2014). Means that within entire mine working stone dust is minimum 80% out of all dust or water content prevents coal dust from floating and disables volatility (Kuai et al., 2011). Frequency of the maintenance work is crucial and it depends on dust deposition in a mine working (Eckhoff, 2003, 2005) Quality and efficiency of protective zones largely depend on the quality of preventive measures undertaken (Cybulski, 2004, Frank, 2004). Changeable mining conditions can influence coal dust deposition, which may result in failure in using protective zones.

Within the framework of MEZAP research project financed by the National Centre for Research and Development was realized by the following consortium: KOMAG Institute of Mining Technology, Central Mining Institute and Kompania Węglowa S.A. Research work was conducted aiming at determination of dust deposition through the measurements of its concentration in a protective zone. Preliminary results of the tests were used in developing the first empirical model of these dependencies (Prostański et al., 2014).

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2. Research methodology

Measurements of dust deposition and dust concentration were taken in protective zone adjacent to longwall no. 121 in Brzeszcze Coal Mine. Measurements of dust deposition were taken by GIG-KD Barbara's specialist (Malich et al., 2013), measurements of the volume and distribution of dust and changes in its concentration were taken by KOMAG's specialists (Prostański et al., 2014).

Additionally the following conditions in the testing area were determined: air temperature, humidity and flow speed. Conditions during tests are presented in Table 1.

Fig. 1 presents a sketch of longwall no. 121 with adjacent mine workings: tailgate (ventilation) and headgate (haulage). Air was delivered to the longwall along the headgate. Then it flowed along the longwall and the tailgate. Average and short-term concentration of dust in the mine workings was measured with optical dust meters PŁ-2.[1] Measurements of deposited dust and dust lying along the whole protective zone were also taken. In both mine workings, the zones were at least 200 m long, starting from the longwall face.

Samples of dust were collected on measuring plates attached to the sidewalls on the left and on the right as well as on the floor of a mine working. Measurements were taken in nine measuring points in a cross-section of a mine working (Fig. 2), in 10 places along the 200-m-long protective zones of the mine workings located in headgate and tailgate.

Measuring points in both mine workings were located 10 m from the longwall. Samples of dust were being collected on measuring plates for a day. The collected samples were processed and analysed. These were divided into 10 measurement size fractions: from 1000 to 20 μm. Measurements were carried out concurrently at all measurement points in both mine workings. Distances between measurement points were 20 m. Mass of total suspended particulate matter (stone dust and coal dust) [g], mass of coal dust [g] and percentage share of non-combustible particles were determined. Total suspended particulate matter deposition and coal dust deposition, expressed in g/m^2/day and g/m^3/day, were determined.

3. Results and discussion

3.1. Test results

Analysis of results of the tests conducted in headgate of longwall no. 121 in Brzeszcze Coal Mine revealed that dust did not deposit evenly in the mine working, especially at the longwall outlet (Fig. 3). Mass of deposited dust reached approximately 9 g/m^3/day at the front of the protective zone.

It was a consequence of dust carried with the stream of air flowing from the longwall at various speeds. Further from the longwall dust was deposited more evenly within the cross section of the mine working (dust deposition was the highest in the central part of the floor in the working).

[1] Optical dust meter is recording on-line dust concentration of dust particulars smaller than 10 μm.

Table 1 – Conditions of tests conducted in haulage mine working no. 551 of longwall no. 121 (Prostański et al., 2014).

No. of measurement point	1	2	3	4	5	6
Distance from the longwall face [m]	10	30	50	65	80	100
Temperature [°C]	25.3	26.0	27.0	28.0	27	27
Humidity [%]	78.9	78.7	76.2	76.8	76.8	76.5
Air flow speed Vp [m/s]	2.5	2.5	2.5	2.4	2.5	2.0

In the tailgate of longwall no. 121 (Fig. 4a) dust deposition in the mine working was caused by intense works related to installation of pipelines and cabling in the section up to 50 m from the longwall. In further part of the mine workings, dust deposition had an undisturbed decreasing tendency outby the longwall. Conveyors transporting coal from the longwall, and the floor (dust raised by the personnel working there) were the main sources of dust.

Dust deposition in the cross-section of the tailgate (Fig. 4b), was more regular than in the headgate.

The empirical model was developed in order to forecast dust deposition in the protective zone.

To assess combustible coal dust deposition, measurements of deposited dust in a mine working were compared with the measurements of air dustiness taken with the optical method (Fig. 5a).

The measured values were marked respectively:

PK – total suspended particulate matter deposited (stone dust with coal dust),
PW – coal dust,
Pł – total suspended particulate matter (stone dust with coal dust) measured with the optical dust meter.

In headgate no. 552 of longwall 121, measurements of dust concentration taken with PŁ-2 dust meter, were conducted in the protective zone along the section between 40 and 170 m. Results of the measurements showed a relationship between dust deposition and results of measurements of dust concentration with optical dust meters.

Results of measurements of dust deposited and air dustiness in tailgate no. 551, longwall no. 121 (Fig. 5b), showed no correlation between dust deposition and dustiness of dust measured with an optical dust meter. Measurements with optical dust meters showed increasing dust concentration in relation to the measured dust deposition within a distance from the front of tested protective zone.

3.2. Model of dust deposition process in mine workings

Test results were described with exponential function. The function enabled showing all the results of tests of air dustiness in the same way, what facilitated comparing the relationships in the mine workings under tests. The volume of total suspended particulate matter deposition and dust concentration measured with an optical dust meter were compared.

Coefficient of determination R^2 of the function is associated with coefficient of indeterminacy φ^2 through the relation: