A statistical determination of methane emission from coalbeds—case study

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Synopsis

In this study, a statistical model is suggested in order to determine the methane emission from a working seam. In the proposed method, methane concentrations which are systematically measured in return airway are the sample values, and the calculated statistical parameter is the upper confidence limit of the average of these values. At any given time, the probability of methane concentration in the return airflow to be lower than the calculated upper confidence limit value is 97.5%. The statistical method has been applied to the panel 206 of Armutcuk Mine, Turkish Hardcoal Enterprises. The calculated methane emission value for the considered shift was 15.18 m³/t.

Introduction

In underground coal mining, for the determination of required airflow quantity, quantity of the methane emitted from coal seams into the atmosphere of the mine is generally taken as the basic parameter. The least amount of airflow to be directed to a working panel is calculated as a value reducing the concentration of methane in the return airway under the maximum allowable value by the legislation (Vutukuri *et al*., 1986).

The gas of methane is assumed to have been formed during the coalification. A considerable amount of methane is released to the surface through the fault and crack planes while the rest is kept in the pores or on the surface of the coal seam as free or bound gas. The gas kept in the seam is under an equilibrium pressure. During the extraction works, this equilibrium is destroyed and the gas is released into the atmosphere along the fractures and cracks (McPherson, 1993).

Many factors have effects on the mechanism of gas diffusion from coal seams, therefore the value of gas contents differ from seam to seam. Many techniques have been proposed to determine the gas content of the virgin strata. These techniques are mainly based either on the laboratory works (Bertard *et al*., 1970; Kissel *et al*., 1973; Diamond *et al*., 1981; Creedy, 1986; Didari *et al*., 1989) or on the empirical methods (Kim, 1977; Dunmore, 1981; Didari, 1988).

The most realistic way to determine the quantity of methane emission from working seams is to evaluate the results of gas measurements taken in the mine. The data recorded in the computer of the mines having continuous monitoring system can be utilized for this purpose. In these mines, either the mean or the highest value of the measured methane content is used in general. However, both approaches include some errors. For the method taking the mean value as the main parameter, the airflow quantity calculated will be insufficient during the period when the gas emission is above the mean value. On the other hand, for the method utilizing the highest value, the airflow quantity conducted to the working panel will be over the required amount resulting in the increase of ventilation cost.

In this work, in order to determine the emission of methane from coal seams more realistically, a statistical model was proposed based on the data obtained from continuous monitoring system.

Statistical method

General

Division of statistics for a number of samples drawn from a main population complies with the normal distribution. This compliance gives the possibility to estimate the statistical parameters of the main population with a certain probability. The function of theoretical normal distribution simulates a symmetrical and bell-shaped curve. In normal division,

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 SA ISSN 0038–223X/3.00 + 0.00. Paper received Oct. 2002; revised paper received Jan. 2003.

basic statistical parameters are the mean (μ) and the standard deviation (σ) (Hines *et al.*, 1990).

At normal distribution graph, area limited by the curve of standard normal distribution is accepted to be equal to 1 or it is represented by the probability of 100%. In normal distribution, samples complying with normal division are supposed to lie in-between the following ranges:

68.27%	$\mu \pm \sigma$
95.45%	$\mu \pm 2\sigma$
99.73%	$\mu \pm 3\sigma$

By means of this feature, confidence interval of the main population average may be estimated using the values of samples drawn from the main population (Sandy, 1990).

The confidence interval evaluation of main population is performed by using mean ($\bar{X}$) and standard deviation (s) values;

$$\bar{X} = \frac{\sum X_i}{n} \qquad [1]$$

$$s = \sqrt{\frac{\sum X_i^2}{n}} \qquad [2]$$

by using these equations standard error can also be found by;

$$S\bar{x} = \frac{s}{\sqrt{n}} \qquad [3]$$

In this case, confidence interval of main population mean value is given for practically and widely used ratios as (Arici, 1993);

for the probability of 95%,

$\bar{X}$-1.96 $S\bar{x} \leq \mu \leq \bar{X}$+ 1.96 $S\bar{x}$

for the probability of 99%,

$\bar{X}$-2.58 $S\bar{x} \leq \mu \leq \bar{X}$+ 2.58 $S\bar{x}$

Formation of the statistical model

Main population for a panel working with longwall extraction method is the methane concentration in the return airway throughout the shift. For the continuous monitoring system, methane content of the return air is measured at short intervals and recorded by a computer in the control centre. The values of methane recorded during the shift form the sample values (X_i) of the model (i = 1, 2, 3, ... n), $\bar{X}$, s and $S\bar{x}$ parameters of the samples are calculated by means of the Equations [1], [2] and [3].

There is no use of lower confidence limit for the problem in concern as the parameter being searched is the upper confidence limit of average methane measurements. Calculations carried out for the upper limit will be valid for the lower limit as well. Taking the upper confidence limit (UCL) as;

$$UCL = \bar{X} + 1.96 S\bar{x} \qquad [4]$$

and accepting it as the methane concentration value of the return airway, 97.5% of the sample data will be counted in the calculation. However, by the use of mean value for methane concentration ($\bar{X}$), half of the sample data will not be taken into consideration.

In order to emphasize the model numerically, let us take the values of methane concentration detected throughout the shift by a sensor as given in Table I. Statistical parameters for these values calculated either by the equations given above or by means of any computer program of statistics are given below;

$\bar{X}$ = 0.6712

s = 0.1995

$S\bar{x}$ = 0.0354

In this case, upper confidence limit is determined as;

UCL = 0.6712 + 1.96 x 0.0354 = 0.7406.

By taking this value as the methane concentration rate, the probability of which the value of methane concentration is lower than UCL at any time is about 2.5%. Using the highest methane value instead of UCL during the calculation of required airflow quantity will result in delivering an unnecessary amount of airflow calculated as below;

(1.15–0.7406) x 100/0.7406 = 55.28 (%).

Using the value of $\bar{X}$ instead of UCL will result in the reduction of required airflow amount as indicated below;

(0.7406–0.6712) x 100/0.07406 = 9.37 (%).

In other words, the probability of realizing an error is reduced to 2.5% by just driving an amount of airflow which is 9.37% more than required amount to the panel. By taking this risk of error, the amount of airflow required for the working panel is decreased by 55.28% in comparison with the choice of the highest methane value. It is, therefore, of high importance to realize that the ventilation power cost is proportional to the cube of the air quantity produced and so a doubling of the ventilation airflow results in eight times of the original power cost (Sensogut, 1989). It is also substantial to emphasize that the cost of ventilation may account for 1/3 of the overall cost (Pearce, 1987).

Case study

The statistical method given above was applied to the panel 206 of Armutcuk Mine, Turkish Hardcoal Enterprises. Additionally, methane emission from the coal seam is defined together with the velocity of airflow.

The face of the panel 206 where the retreating longwall system is utilized to extract the coal is 120 m long and has the inclination of 17–20°. Lower roadway of the panel is

Table I

Measured values of methane sample

Concentration of methane (%)

0.32	0.38	0.45	0.58	0.47	0.62	0.65
0.77	0.63	0.82	0.96	0.94	1.15	1.02
0.92	0.86	0.82	0.76	0.62	0.57	0.59
0.53	0.55	0.62	0.49	0.54	0.52	0.65
0.82	0.71	0.58	0.56	0.57		

Calculated statistical parameters

Number of data	33
Mean value	0.6712
Standard deviation	0.1985
Highest value	1.15
Standard error	0.0354

463 m deep while the upper roadway is 450 m deep. A total of 165 miners are working at the face throughout three shifts. The gas content of the return airway is detected by the sensor 206 placed in the return airway of the panel 206. The measurements are sent to the control centre on the surface and recorded by a computer in this centre.

A total of 35 samples were collected in the period of 7 hours at every 12 minutes from the sensor 206. In addition, the velocity of the airflow was also measured around the section where the sensor was placed. The data collected and the parameters obtained using the data in concern are given in Table II. The statistical parameters were evaluated by means of the software program STATISTICA.

It is more suitable to take the upper confidence limit which is 1.106% as the methane concentration of the return airway. In this case, methane production will be;

8,106 x 0,01106 = 0,0897 m^3/s

and the production of methane for the shift in concern will be;

0,0897 x 3600 x 8 = 2583,4 m^3/shift

This value has been obtained by the evaluation of the measurements taken in only one shift. It is to note that the data which is to be taken for a longer period will lead to more realistic results.

Another point which should also be considered is the methane content of the fresh air entering the panel. A sensor being supposed to detect the methane content in concern should be placed somewhere at the entrance of the panel and the values of methane content determined by this sensor should be extracted from the values determined for the return airway.

Table II

Measured values of methane for the panel 206 and calculated statistical parameters

Concentration of methane (%)

1.08	1.02	1.02	1.02	1.02	1.02	1.02
1.02	1.02	1.02	1.02	1.02	1.02	1.02
1.02	1.02	1.02	1.02	1.02	1.02	1.02
0.98	0.98	0.98	0.98	0.98	0.98	0.98
0.98	0.98	0.98	0.92	0.92	0.95	0.95

Calculated statistical parameters

Number of data	35
Mean value	0.9983
Standard deviation	0.3258
Highest value	1.08
Standard error	0.0551
Upper confidence limit	1.106

Information related to the panel

Velocity of airflow	1.93 m/s
Cross-section of airway	4.2 m^2
Airflow quantity	8.106 m^3/s
Coal production	170 tonnes/shift

Results

For the determination of the methane emission from a working panel, the most realistic way is to evaluate the results of the gas measurements statistically. In the statistical method, methane concentrations observed for the return airway are taken as the basic values and the statistical parameters are calculated for them. In order to calculate these parameters, any computer program of statistics can be used. By the evaluation of these parameters, upper confidence limit of sample values can be determined. By also taking the upper confidence limit calculated as methane concentration rate of the return airway and utilizing it in the calculation of required airflow quantity, 97.5% of the sample data will have been included in the calculation. The probability at which the methane concentration is over this limit is only 2.5% at any time.

By the application of the suggested statistical method to the panel 206 of Armutcuk Mine, the methane emission rate from the working panel is calculated to be around 15.18 m^3/t. In order to have even more realistic results, the work in concern should be carried out with more data obtained in longer period instead of only one shift period.

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