AGH Journal of Mining and Geoengineering • vol. 36 • No. 3 • 2012

*Mirosław Wierzbicki**

STATISTICAL RELATIONSHIP BETWEEN METHANE DESORPTION RATE INDEX AND COALBED METHANE CONTENT ON THE BASIS OF COAL MINE "ZOFIÓWKA" MEASUREMENTS

1. Introduction

Coal seam methane content (*Mn*) is defined as the volume of natural methane contained in the unit of weight. This parameter is one of the most important parameters determining the gas and coal outburst in all coal basins of the world [3]. Review of methods for assessing methane deposits in the Polish coal mining industry and the world can be found in [4].

Borehole method is method used for accurate determinations of the coal seam methane direct in Polish coal mines. To determine the amount of methane using a sample of cuttings taken from a borehole in the forehead of the excavation to the air-tight container. Volume of methane desorbed during drilling and sampling. The gas obtained in the degasification process is analyzed in gas chromatography, which allows to determine the share of hydrocarbons in the all gas included in the coal. In this way, a volume of methane contained in the container is measured. Coalbed methane content is defined as the sum of the following components:

$$M_n\ [\mathrm{m^3/Mg_{csw}}] = V_u + V_o + V_w + V_r \tag{1}$$

where:
- V_u — volume of methane desorbed during drilling and sampling,
- V_o — volume of methane obtained in the degasification process,
- V_w — volume of free methane lost during drilling and sampling,
- V_r — volume of residual methane content after the sample degasification.

* Strata Mechanics Research Institute of Polish Academy of Sciences, Krakow

Desorbometric is one main important method of the indirect method of coal seam methane content measurements. Desorbometric method is used to estimate coal seams methane content in case, when there is a need for more measurements, and also to examine the trend of methane deposits during mining operations. time-consuming laboratory analysis of samples has been eliminated in this method. Desorption intensity ratio *dp* is characterizing the amount of methane released from a specific weight of carbon in the specified time frame. In various variations is applied in the coal mining industry in many countries [3]. In the Polish coal mining desorbometric test is carried out with use liquid described in the works [3, 6, 10].

Desorbometric method has several advantages:

— all measurements are made in the underground, and the results are obtained in a very short time (few minutes);
— device used for determining *dp* index has a simple construction and is very reliable,
— large number of studies indicate a correlation between *dp* and *Mn* for eg. [1, 2, 7–9].

It should be pointed out that the quality of the index dp is highly influenced by the rigorous observance of the temporary regime.

2. The results of coal seam methane content measurement and analysis

During 2008–2011 years 779 measurements of coal seam methane content were made in the coal mine "Zofiówka". Methane desorption rate index *dp*, Protodiakonov strength index *f*, and coal technical parameters. were determined in this measurements. Table 1 shows the number of measurements made in coal mine, the averages values of the coalbed methane capacity, gas desorption rate index, Protodiakonov strengths index and volatile matter content (V^{daf}).

TABLE 1

Summary of results of measurements made in the coal mine "Zofiówka" in 2008–2010

	Numbers of measurements	*Mn* [m^3/Mg_{csw}]	*dp* [kPa]	*f*	V^{daf} [%]
2008	290	3.518	0.591	0.383	26.4
2009	209	3.116	0.504	0.382	25.9
2010	280	3.529	0.666	0.382	23.0

Average *Mn* varied in the range from 3.12 to 3.53 m^3/Mg_{csw}. Average values of gas desorption rate index *dp* varied in the range of 0.59 to 0.67 kPa. In subsequent years have seen a decrease of volatile matter content. Protodiakonov strength index has a constant value of about 0.38.

The graphs of Figures 1–3 shows the relationship between the *dp* ratio, and the methane content *Mn* for all measurements made in all the seams in analyzed period. With these removed results in which the desorption rate was zero. For measuring points, used the method of least squares regression line passing through the origin was fitted: $Mn = a\ (dp)$. Laboratory tests showed that the course of the function $dp = f(P)$ has a character similar to the sorption isotherms [5]. Volume of gas released during the first minutes of desorption process should be proportional to the initial methane content in the sample. It is linked to pressure via the sorption isotherm curve. For this reason, the data points were fitted regression equation in the form of Langmuir:

$$Mn = \frac{ABdp}{1 + Bdp} \tag{1}$$

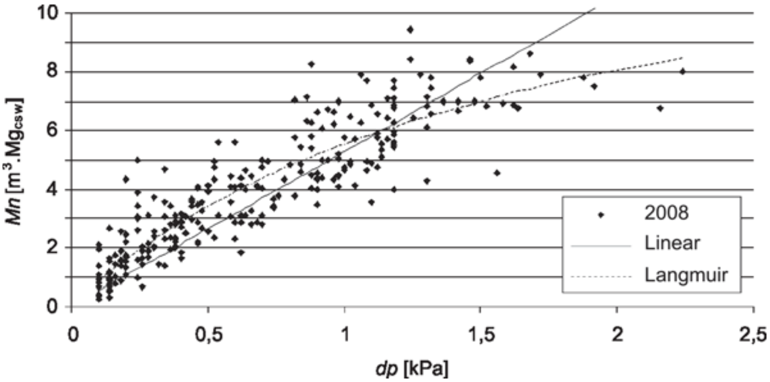

Fig. 1. The relationship between the methane capacity,
and the desorption rate index *Mn* (*dp*) with linear fit and the Langmuir curve. Year 2008

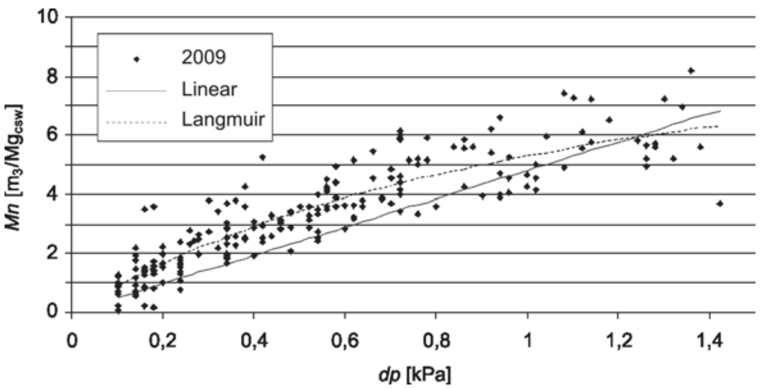

Fig. 2. The relationship between the methane capacity,
and the desorption rate index *Mn* (*dp*) with linear fit and the Langmuir curve. Year 2009

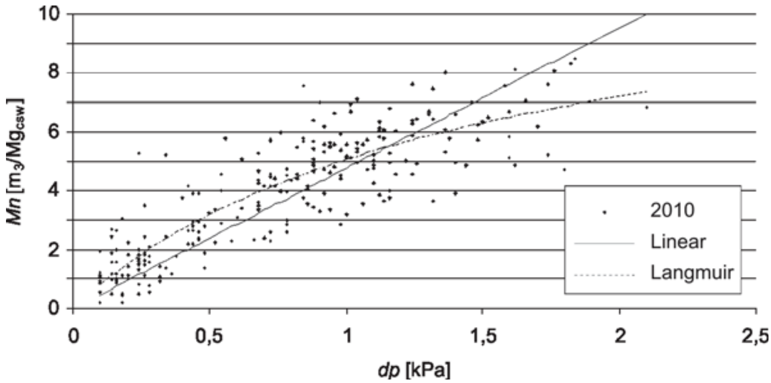

Fig. 3. The relationship between the methane capacity,
and the desorption rate index *Mn* (*dp*) with linear fit and the Langmuir curve. Year 2010

Tables 2 and 3 shows a simple regression coefficients a m^3kPa/Mg_{csw}], the coefficients of the Langmuir curve (A and B) and the most important statistical information about the match:

n — numbers of measurements,
RSS — Residual sum of squares,
MSR — Mean-square residual:

$$MSR = \frac{RSS}{n-1},$$

$Mn_{śr}$ — average methane capacity,
CV — coefficient of variation, calculated from the equation:

$$CV = \frac{\sqrt{MSR}}{Mn_{AV}}.$$

TABLE 2
Fitting a linear regression

	2008	2009	2010
A	5.2919	5.6306	4.7724
N	257	200	248
RSS	359.47	191.22	353.67
MSR	1.404	0.961	1.432
Mn_{AV}	3.968	3.621	3.881
CV	0.30	0.27	0.31

TABLE 3

Fitting regression — Langmuir curve: $Mn = \dfrac{ABdp}{1 + B(dp)}$

	2008	2009	2010
A	14.664	11.768	12.340
B	0.6099	0.8236	0.6937
N	257	200	248
RSS	238.06	120.37	246.17
MSR	0.930	0.605	0.997
CV	0.24	0.21	0.26

Assume that the coefficient of variation is a measure of the uncertainty of determining the methane content in coal seams. In this situation, estimation of methane on the basis of linear *Mn* (*dp*) has an average uncertainty of 29%. The uncertainty of determining methane content using the Langmuir equation, ranged from 21 to 26% of measured values. The graphs of Figures 4–6 shows the change in value the sum of squared deviations (*RSS*) for the dependence of *Mn* (*dp*) with linear approximation and the Langmuir curve for increasing *dp* values.

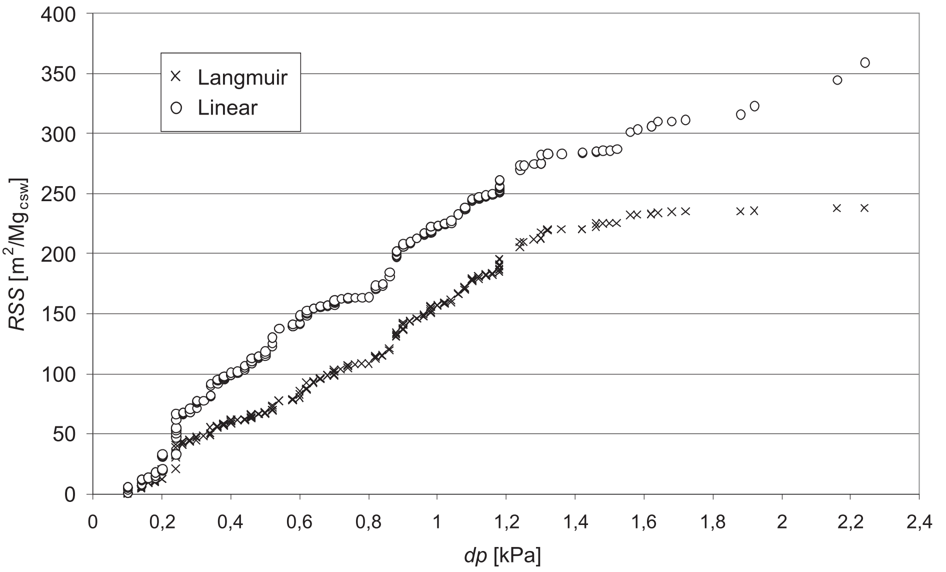

Fig. 4. Sum of squares of deviations as a function of *dp* values for linear and curve fitting Langmuir, year 2008

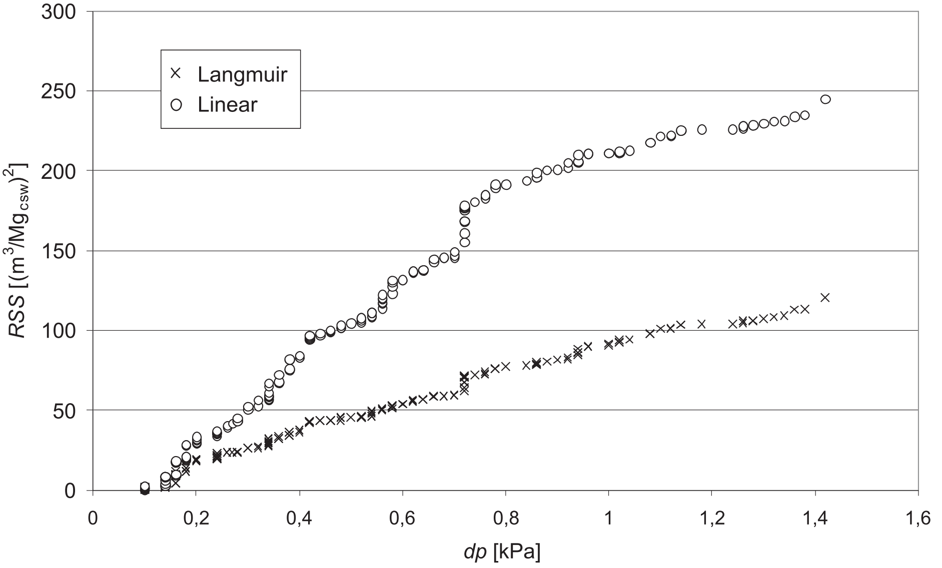

Fig. 5. Sum of squares of deviations as a function of *dp* values for linear and curve fitting Langmuir, year 2009

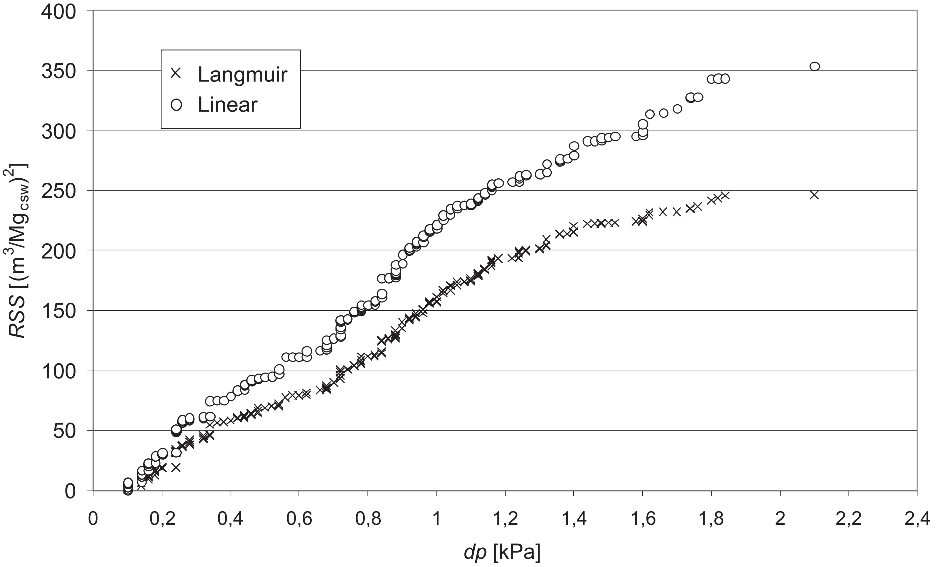

Fig. 6. Sum of squares of deviations as a function of *dp* values for linear and curve fitting Langmuir, year 2010

Is clearly visible that the sum of squares of deviations for the Langmuir curve fitting have lower values that the sum for linear function for all values of *dp* index.

Introduce the parameter D which is the quotient of the sum of squared deviations for linear regression, and regression of the Langmuir:

$$D = \frac{(RSS)_{lin}}{(RSS)_{lang}}.$$

Changes in the value of the D parameter as a function of methane desorption rates for studied years are shown in Figure 7.

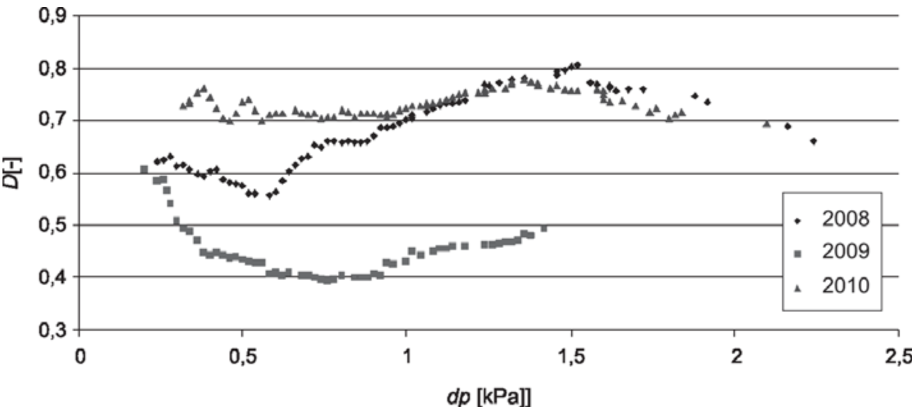

Fig. 7. The dependence of the parameter D from the values of methane desorption rate index dp

The values of $D < 1$ show that in the whole range of variation dp ratio Lagmuir equations gives better results in methane content determination using the indirect method, than linear eqations. The sum of squared deviations for the linear fit (RSS_{lin}) is 1.25x to 2.5x greater than the sum obtained for the Langmuir equation fit (RSS_{lang}). The chart shows that it is difficult to observe a particular value of dp, for which differences in the quality of approximation according to Langmuir and linear curve begin to significantly differentiate. Regression equations (linear and Langmuir) may also be designated for each seams, which in 2009–2011 carried out measurements of methane content and the gas desorption rate indexes. Such statement, made to the seams, which made more than 20 measurements are presented in Tables 4 and 5. To analyze all the results of measurements taken, regardless of the year in which the measurements were made.

The coefficients of linear regression equations presented in Table 4, range from 4.59 to 6.51 m^3kPa/Mg_{csw}. Differences in rates probably due to different kinetic properties of the methane in coal seams. The increase in value as evidenced by the reduction of diffusion coefficient *De*.

TABLE 4
Statistics for the seams — a linear equation: $Mn = a\,(dp)$

Seam	**410**	**404/4**	**406/1**	**412**	**413/2**	**416/3**	**417/1**	**418**	**502/1**
A	5.75	5.29	5.07	4.59	4.94	5.27	6.32	6.27	6.51
N	96	72	121	82	77	18	58	23	80
RSS	136.4	95.2	173.2	131.9	120.2	52.7	41.8	10.3	2595
MSR	1.436	1.342	1.444	1.629	1.583	3.102	0.735	0.472	0.329
Mn_{AV}	4.43	3.93	4.67	5.48	3.77	4.71	2.39	2.27	1.35
CV	0.27	0.29	0.26	0.23	0.33	0.37	0.36	0.30	0.27

TABLE 5
Statistics for the seams — Langmuir curve

Seam	**410**	**404/4**	**406/1**	**412**	**413/2**	**416/3**	**417/1**	**418**	**502/1**
A	16.16	7.29	14.56	10.74	10.27	6.27	9.36	5.63	40.00
B	0.58	1.79	0.60	0.95	0.95	5.01	1.11	2.10	0.17
N	96	72	121	82	77	18	58	23	80
RSS	88.4	62.6	110.7	84.8	76.64	19.5	29.3	7.7	26.0
MSR	0.93	0.88	0.92	1.05	1.01	1.15	0.52	0.32	0.33
CV	0.22	0.24	0.21	0.19	0.27	0.23	0.30	0.25	0.22

Also interesting is the analysis and the coefficient of variation a for individual seams, as shown in Figure 8. Values a reaches minimum value for the coal seam 412 and then increases, reaching a maximum value for the 502 seam.

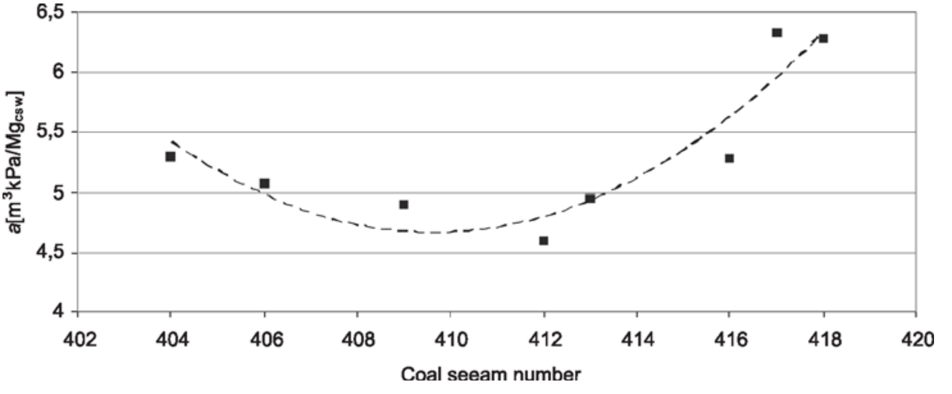

Fig. 8. The variability of the linear regression coefficient for the seams in coal mine "Zofiówka"

Uncertainty in the *Mn* determination (using the indirect, desorption method) for different seams, using the Langmuir equation for the chosen eight seams of the coal mine "Borynia-Zofiówka" ranges from 19 to 30%.

3. Discussion

Determination of linear regression equations and the Langmuir equations for seams allows the estimation of methane content of the seams from the methane desorption index *dp*. Average uncertainty of coal seam methane content determination, using the indirect method, with the Langmuir equation is 24% of value measure. Improving the quality of the designation of *Mn* can be obtained using the regression equation for each coal seams. To assess the quality of the method of indirect determination of *Mn*, obtained uncertainties should be compared with those uncertainties obtained with using the direct borehole measurements method.

Comparative studies were held marking coal seam methane content was made in 2007. In these studies, took part in specialized research laboratories. Two rounds of comparative research were made. In the first round, which was attended by four laboratories, the average *Mn* was determined to 5.1 m^3/Mg_{csw} and the coefficient of variation was $CV = 19.6\%$. In the second round, which was attended by seven laboratories, the average *Mn* was determined at 3.89 m^3/Mg_{csw} with the coefficient of variation of $CV = 23.7\%$. The results of comparative measurements we can find in work Ryszka i Sporysz [4].

Statistical analysis results presented in the paper, shows that the coal seam methane content measurements made by the indirect method are very similar to the uncertainty resulting measurements made in approved laboratories by the direct method. This result is a surprise for the author, since the direct measurements are required to have lower uncertainty than simply measurements with use indirect, desorbometric method. It seems that reducing the random uncertainty of measurement *dp* can significantly reduce the uncertainty of the statistical method of determining methane content.

REFERENCES

[1] *Borowski J.*: Determination of gas pressure in coal seams, Przegląd Górniczy 9, 1976 (in polish).

[2] *Borowski J.*: Determination of gas content In coal seams manometric desorbometer, Bezpieczeństwo Pracy w Górnictwie, 1975, nr 4, (in polish).

[3] *Lama R. D., Bodziony J.:* Outburst of Gas, coal and Rock in Underground Coal Mines, R.D. Lama & Associates, Wollongong, NSW Australia 1996.

[4] *Ryszka M., Sporysz G.*: Verification of direct designation method of methane content in coal seams. Part II — Comparison of methane designation resultsBezpieczeństwo Pracy i Ochrona Środowiska w Górnictwie, 8, 2008. (in polish).

[5] *Skoczylas N.*: Selected mechanical and gaseous properties of coal briquettes, Przegląd Górniczy 7–-8, 2009 (in polish).

[6] *Stączek A., Simka A.*: Bonduary gas desorption index from coal as a methane and gas and methane risk, Prace Naukowe GIG - Górnictwo i Środowisko, 3/2004, 123–142 (in polish).

[7] *Szlązak N., Borowski M., Korzec M.*: Determination of methane content of coal seams according to measurements of the desorption index for the southern part of upper silesian coal basin, Materiały konferencyjne XX Szkoły Eksploatacji Podziemnej, 21–22 lutego 2011 (in polish).

[8] *Szlązak N., Borowski M., Korzec M. Obracaj D.*: The project of the standard for determining methane-bearing capacity in coal seams, Wybrane zagrożenia aerologiczne w kopalniach podziemnych i ich zwalczanie (Selected hazards and their control in underground mines). Kraków: Wydawnictwa AGH, 2011. — ISBN 978-83-7464-429-7. — S. 25–39 (in polish).

[9] *Szlązak N., Borowski M., Korzec M.*: Określenie metanonośności pokładów węgla na podstawie pomiarów wskaźnika desorpcji dla południowej części Górnośląskiego Zagłębia Węglowego, Materiały konferencyjne XX Szkoły Eksploatacji Podziemnej, 21–22 lutego 2011. (in polish).

[10] *Tarnowski J.*: Desorbometryczna metoda pomiaru ciśnienia gazu w pokładzie węgla. Zeszyty problemowe górnictwa. PAN 1966, t. II, z. 2, 1966.

[11] *Wierzbicki M.*: Analysis of desorption index variation by application of method of movable averages, WUG, Bezpieczeństwo pracy i ochrona środowiska w górnictwie, Nr 3 (139), 2006, str. 22–27 (in polish).