WORLDWIDE EXAMPLES OF COAL MINE METHANE EMISSION AND GOB GAS PRODUCTION MODELING

MSc. Eng, Jacek Hendel[1]

DSc., PhD. Eng, Jan Macuda[1]

PhD. Eng. Jarosław Chećko[2]

[1]AGH - University of Science and Technology, 30 Mickiewicza Av., 30-059 Kraków, **Poland**
[2] Central Mining Institute, Plac Gwarków 1, 40-166 Katowice, **Poland**

ABSTRACT

Coal Mine Methane (CMM) could be valuable source of energy for electricity and heat production. On the other hand, methane migration from gobs, through overburden strata, to the atmosphere, has non-negligible influence on global warming effect. Accidents caused by uncontrolled methane migration, from abandonment coal mines, are also commonly known. In this article worldwide and Polish experiences of CMM migration modeling are shown. Short review of CMM utilization are also presented. Authors discussed several models of gases migration and accumulation in overburden strata in the area of "1 Maja" and "Niwka-Modrzejów" abandoned hard coal mines. Petro-physical parameters used to numerical model building are shown. Results of gases migration modeling are collected and pointed out. Model of methane production from "Moszczenica" hard coal mine is also considered. In addition, some American experiences of coal mine methane exploitation from gobs are also discussed within this article.

Keywords: coal mine methane (CMM), gobs, gas migration modeling

INTRODUCTION

Coal Mine Methane (CMM) could be valuable source of energy for electricity and heat production. During hard coal extraction and preparation processes, methane emission could be observed. Cheng et al., [1] and Environmental Protection Agency [2] pointed out several possible ways of methane exhalation: during underground coal seams degasification (as known as drainage operations); within mine ventilation air; from abandoned coal mines, from open pit mines and, finally, fugitive emission from post-mining coal processing [1]. CMM term, generally, has two main meanings: coal mine Ventilation Air Methane (VAM) and Abandoned Mine Methane (AMM) [3]. VAM is a mixture of origin gas from coal seams (mostly methane) and ventilation air (methane must have a concentration below the lower explosive limit, commonly VAM has methane concentration lower than 1%)

VENTIALTION AIR METHANE EMISSION AND UTILIZATION

In 2009, China emitted 18,2 Bcm VAM what accounted for 52,7% of global VAM emission [2]. American and Ukrainian VAM emission were amounted to 2,8 and 2,6 Bcm respectively (8,1% and 7,5% of worldwide) [2]. In 2009, Australia and Russia emitted 1,3 and 1,0 Bcm VAM respectively (3,8% and 2,9% of global emission) [2]. It should be noted, that global CMM production amounts from 8,9% to 12,8% worldwide anthropogenic methane emission [4], [5]. Although VAM from shafts of active hard coal mines is responsible for about 64% of total methane emission from coal mining [6], different methane concentration in various mines are received [6] - [9]. Due to different gas composition and methane concentration various methods of gas utilization are considered and used. In 2013, Polish hard coal mining industry emitted 571,21 Mcm of pure methane in VAM. In addition 276,58 Mcm was captured while mining by drainage methods. Table 1 shows methane emission and utilization efficiency in Polish hard coal industry, in 2013. [10]

Table 1. Status of Polish hard coal industry methane emission and utilization (2013) [10]

Hard Coal Mine	Drainage methane in 2013 [Mcm/year]	Usage of drainage methane [%]	VAM in 2013 [Mcm/year]	Total methane emission in 2013 [Mcm/year]
Bielszowice	11,84	11,91	27,97	39,81
Budryk	19,93	59,36	37,08	57,01
Halemba-Wirek	1,98	77,78	9,28	11,26
Knurów-Szczygłowice	19,75	41,10	24,38	44,13
Sośnica-Makoszowy	13,63	51,21	28,68	42,31
Pokój	0	0	2,41	2,41
Bolesław śmiały	0	0	0,72	0,72
Bobrek-Centrum	0	0	0,19	0,19
Brzeszcze	36,16	100,00	56,8	92,96
Silesia	6,87	32,02	14,71	21,58
Murcki-Staszic	18,31	88,55	40,85	59,16
Mysłowice-Wesoła	15,6	61,15	40,17	55,77
Wujek	2,75	31,64	15,6	18,35
Wieczorek	0	0	21,89	21,89
Rydułtowy-Anna	6,22	n/d	32,38	38,6
Chwałowice	5,65	100,00	9,33	14,98
Jankowice	2,83	90,46	15,95	18,78
Marcel	3,53	58,92	19,65	23,18
B-Z-J (Borynia)	4,77	91,19	15,65	20,42
B-Z-J (Zofiówka	14,36	95,19	30,69	45,05
B-Z-J (Jas-Mos)	8,76	86,76	11,36	20,12
Pniówek	37,15	91,92	81,87	119,02
Krupiński	46,49	66,85	33,6	80,09
Total	**276,58**		**571,21**	**847,79**

GOB GAS PRODUCTION MODELING

As previously was pointed out, methane, emitted from coal during exploitation process, could be valuable source of energy. Numerical simulation of gas accumulation in gobs (goafs) is sophisticated problem. Sorption, migration, diffusion, as well as geomechanical issues should be considered. In this chapter some worldwide examples of modeling of methane flow and accumulation are presented. In 2012, Stopa & Nawrat [11] showed results of modeling of CMM methane production from "Moszczenica" abandoned hard coal mine. Mine has been closed since 2000, after 36 years of hard coal production. In this region of Upper Silesian Coal Basin (USBC) extremely high value of gas content was obtained. In the region of "Moszczenica" exploitation methane content reached values up to 16 standard cubic meters per metric ton of coal (d.a.f. - dry, ash free) [11]. In article [11] water presence, geomechanics of coal seams, as well as changes in porosity and permeability of coal plays were not considered. Numerical model was built in Schlumberger Eclipse commercial simulator [11]. Program was used to determine of gas production and to choose the optimal location of new wells, which should be drilled to maximize AMM production. Detailed information about model is presented within paper [11]. Fig. 1. shows model of ventilation system used during numerical simulation. Fig. 2. presents methane saturation in model cells, in 2008.

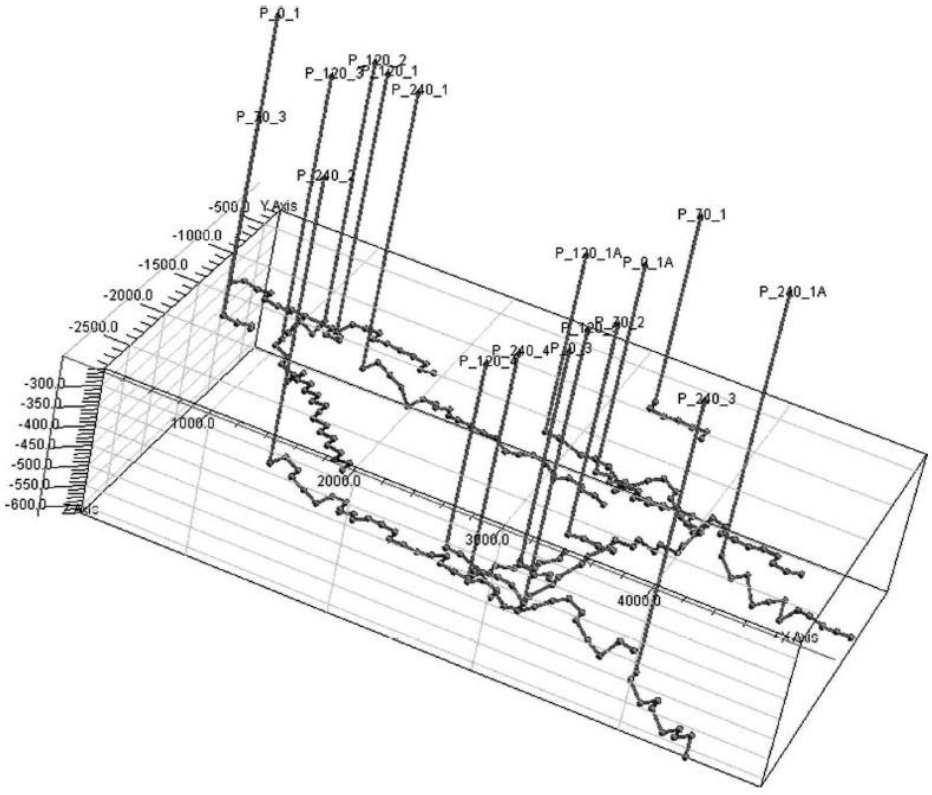

Fig. 1 Model of ventilation system built in Eclipse [11]

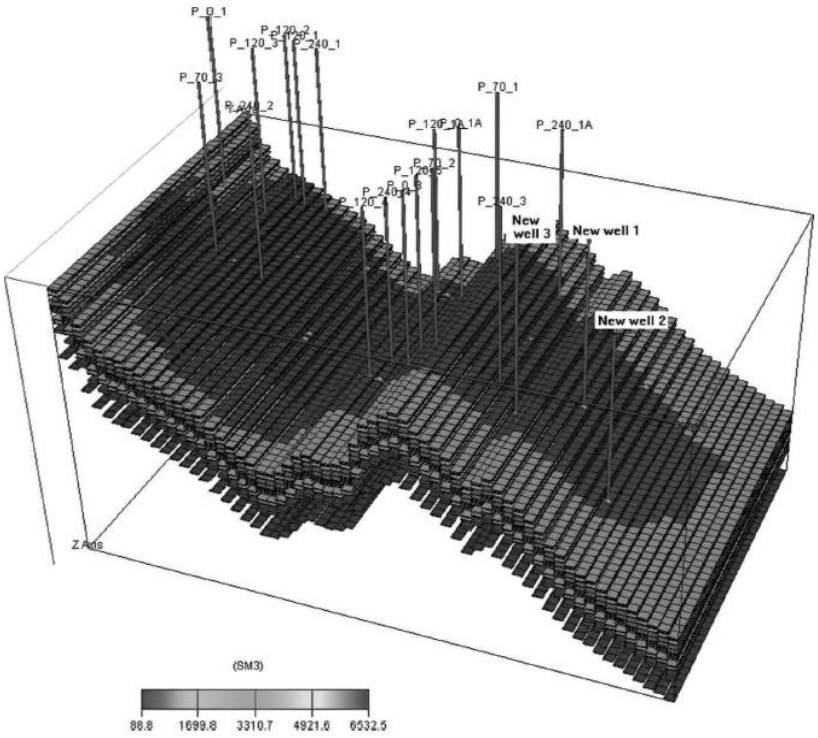

Fig. 2. methane saturation in model cells [11]

Among articles discussing CMM/AMM gas production, Ren & Edwards [12], Lunarzewski [13], Tomita et al. [14], as well as Karacan et al., [15] papers have to be mentioned. Ren and Edward used a CFD (Computational Fluid Dynamics) technique to determine CMM production by wells drilled from surface [12] [15]. Efficiency of gob gas production strongly depend of wells placement. It is a main conclusion of [12] and [13] investigation. Tomita et al. [14] used 3D finite element model (FEM) to forecast methane emission from coal plays and surrounding strata. Within this model dimensional variation of permeability was adopted [14] [15]. In 2006 Karacan et al., built 3D reservoir model of a multi-panel Pittsburgh coalbed mine. Commercial, compositional reservoir simulator GEM was used in investigations [15]. Permeability and mechanical of rock properties were previously obtained using FLAC-2D software. Detailed values of mechanical properties of strata surrounding were presented previously in 2005 [16]. The model of gob gas production from typical Pittsburgh mine, located in the Appalachian Basin in south-western Pennsylvania, was calibrated based on real data from ventholes [15]. The main object of that works was to obtain the influence of wells completion and diameter for CMM/AMM gas production. The results, discussion and some remarks are presented in paper [15]. Fig. 3. shows methane mole fraction concentration in panels 670 days after coal exploitation start.

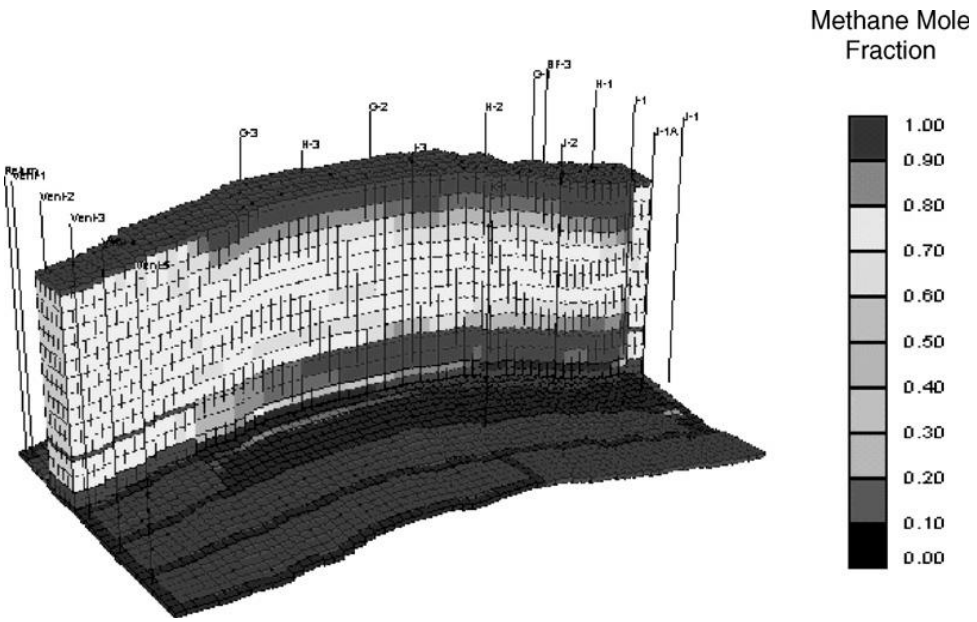

Fig.3. A vertical cross section of the subsided strata reservoir and the Pittsburgh coalbed layer 630 days after the start of mining [15]

MODELING OF GAS MIGRATION IN OVERBURDEN STRATA

Uncontrolled migration of gas from abandoned coal mines, through overburden strata, to the atmosphere is a serious, dangerous problem. This problem is commonly connected with flooding occurring in areas of abandoned coal mines' activity. Gremla et al., 2006 [17] discussed problem of uncontrolled methane migration occurrences in the area of the Ostrava Trough and the Petřvald Trough (Czech part of Upper Silesian Coal Basin). The special program of prevention accidents, caused by explosive gas' migration to surface, was proposed within article [17]. The Polish experience of modeling gas migration was presented by Checko, in 2007 [18]. In that paper, TOUGH numerical simulator was employed to modeling migration of methane and carbon dioxide, through strata, to surface. To model calibration, geochemical research were performed. Geology of USCB, including stratigraphy and tectonics, was deeply investigated. Many maps of porosity and permeability distribution, as well as thickness were prepared. Empirical equations connecting porosity and depth were proposed. Gas migration time through strata was measured. Finally, 3D models of gas saturation were created [18]. On Fig. 4. a) and b) gas saturation in carbon overburden strata, in the area of "Niwka-Modrzejów" abandoned coal mine, is shown (after 5 years of mine close) [18]. Fig. 5 a) presents gas saturation after 5 years of mine close in the area of "1 Maja" abandoned hard coal mine [18]. On Fig 5 b) pressure in overburden strata is shown[18].

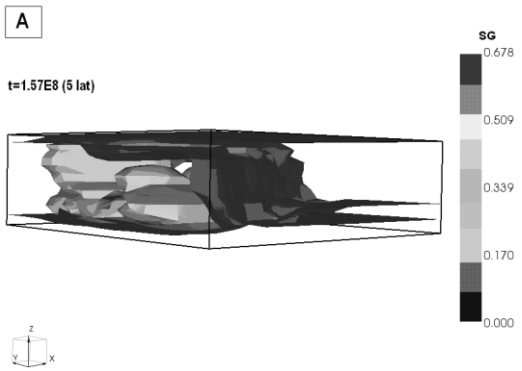

Fig. 4 a) 3D projection of gas saturation in "Nikwa-Modrzejów" overburden strata [18]

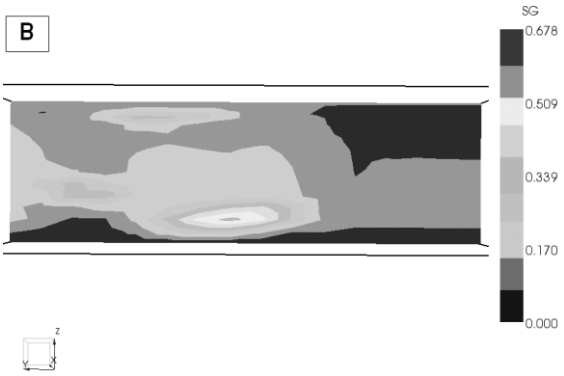

Fig 4 b) North-South section of gas saturation in "Nikwa-Modrzejów" overburden strata [18]

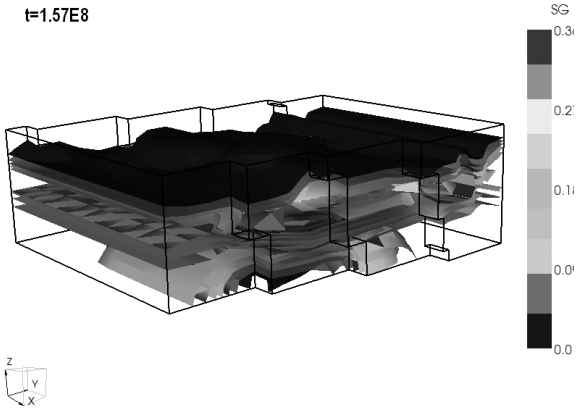

Fig. 5 a) 3D projection of gas saturation in "1 Maja" overburden strata [18]

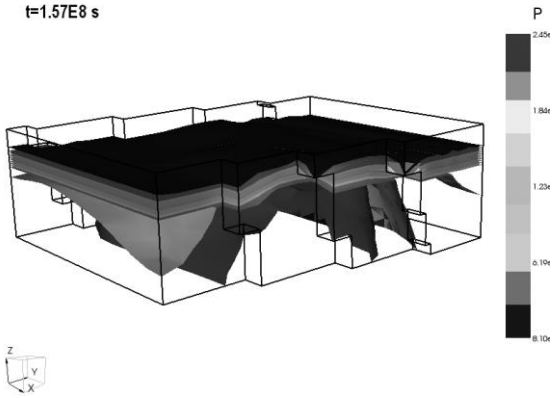

Fig 4 b) Pressure 3D distribution in "N1 Maja" overburden strata [18]

CONCLUSION

This review article summarizes some Polish and worldwide experiences of gas (methane) migration modeling. Because of greenhouse potential of methane, as well as opportunities of explosive occurrences, capture of methane should be considered. Heat and electricity production from this gas could be clean, environmentally friendly and profitable way of methane utilization.

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