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Jan Macuda*, Łukasz Łukańko*, Jacek Hendel*

THE MULTICRITERIA METHOD FOR SELECTING RIGS FOR DRILLING GAS WELLS FROM POST-MINING GOBS**

1. INTRODUCTION

Methane stored in gobs, abandoned pathways/shafts and crushed strata (formed during underground hard coal mining) could be a valuable energy carrier in actual (or post-) mining areas. On the other hand, this greenhouse gas (GHG) when released into the atmosphere contributes to global warming processes. Only in 2015, the Polish hard coal mining industry emitted 840 million m^3 of methane. 522.62 million m^3 as ventilation air methane (VAM) and 316.85 million m^3 as coal mine methane (CMM) [22]. Detailed information and the database about Polish hard coal mining industry emissions have been published by Patyńska [17, 18]. The EPA (U.S. Environmental Protection Agency) and GMI (Global Methane Initiative) [1, 25] calculated that global methane emissions from the coal mining industry worldwide had reached 401 million tonnes of CO_2 equivalent (1 tonne of $CH_4 \approx 21$ tonnes of CO_2) in 2000. Because of economic, ecological as well as safety reasons, extraction and utilization of coal mine methane (CMM), abandoned mine methane (AMM) and ventilation mine methane (VAM) should be considered and implemented in the hard coal mining industry and in post-mining areas. Several examples of global projects focused on the extraction and production of CMM/AMM were presented within papers [6, 11, 9, 19, 21, 26].

Nowadays, traditional rotary drilling technology with rotary table or top-drive systems is commonly used to drill vertical boreholes up to 1000 m [5, 13]. Unfortunately, workings with a classic mud are very risky when drilling boreholes through crushed strata and unconsolidated layers formed due to underground hard coal mining extraction. Within the GEKON project (grant no GEKON1/O1/213764/10/2014) realized at the AGH Drilling, Oil and Gas Faculty, the implementation of Casing-While-Drilling (CwD) technology was proposed to solve this prob-

* AGH University of Science and Technology, Faculty of Drilling, Oil and Gas, Krakow, Poland

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lem. The authors also suggested using top hammer or down-the-hole hammer technology to increase the probability of success and cut the total costs of operations. Detailed information was presented in papers [4, 5, 13]. During the realization of the project a pilot borehole was drilled and a down-the-hole hammer with CwD technology was implemented. The Wieczorek-AGH borehole opened 5 different gob layers and was made extremely fast without any complications.

The complex issues of CMM vertical wellbores productivity were described in Pachik's paper [16]. Several other articles showed the adaptation of the multiple rate drawdown well test technique, as well as a decline curie analysis to predict original gas in places (OGIP) in drilled gob layers [2, 8]. Advanced stochastic methods were also applied for predicted methane extraction and for choosing the best location for future production wells [10, 11].

When drilling wellbores from the surface to start the production of coal mine methane from post-extraction coal gobs, special attention should be paid to the type of rigs used. These should have the optimum technical parameters and be adjusted to the geological setting, wellbore design and drilling technology, to provide high drilling rates and lower cost of drilling. The type of rig can be correctly selected using the multicriteria optimization method with a synthetic evaluation of the technical parameters. Accordingly, the technical parameters of rigs available on the Polish market were reviewed in detail. This analysis was performed in view of geological setting and depth of post-extraction coal gobs. Two groups of rigs were distinguished on the basis of the geological-drilling conditions and depth of gobs: rigs which may efficiently operate to a depth of ca. 500 m, and over 500 m.

2. METHODOLOGY OF SELECTING DRILLING RIGS WITH THE MULTICRITERIA OPTIMIZATION METHOD WITH A SYNTHETIC EVALUATION MEASURE

The rigs for drilling wellbores to start the production of coal mine methane from post-extraction coal gobs can be selected with the multicriteria method with a synthetic measure of technological parameters evaluation. This method allows for the practical comparison of various criteria in view of their measure and weights. All criteria are reduced to dimensionless values, thanks to which they can be compared [20, 23]. The number of criteria assumed for the evaluation of rigs can be arbitrary [30].

In this method the rigs can be fully compared. Here the weight criteria (W) and minimum or maximum functions were established [14]. For the matrix of criteria $[x^l_{jk}]$, where:

l – 1, 2, ….. z, number of analyzed groups of rigs,

j – 1, 2, ….. u, number of rigs in a given group,

k – 1, 2, ….. h, number of assumed criteria,

applying the following procedure allowing for synthetic evaluation [3, 14]:

- establishing weight (W) for the particular evaluation criteria for rigs. The sum of assumed weight values should equal zero,
- determining the minimum maximum values of particular criteria

$$x_k^{\min} = \min x^l_{jk} \qquad k = 1, 2, \ldots, h \tag{1}$$

$$j = 1, 2, \ldots, u$$

$$x_k^{\max} = \max x^l_{jk} \qquad l = 1, 2, \ldots, z \tag{2}$$

– calculating the range of particular criteria

$$r_1 = x_k^{\min} - x_k^{\max} \qquad k = 1, 2, \ldots, h \tag{3}$$

– transformation of matrix $[x_{jk}^l]$ of values of particular criteria to matrix $[y_{jk}^l]$ of values from the formula

$$y_{jk}^l = \begin{bmatrix} \dfrac{x_{jk}^l - x_k^{\min}}{x_k^{\max} - x_k^{\min}} & \text{for} \quad k = \min \\ \dfrac{x_k^{\max} - x_{jk}^l}{x_k^{\max} - x_k^{\min}} & \text{for} \quad k = \max \end{bmatrix} \tag{4}$$

– calculating the synthetic value of measure d_j^l being the distances between particular criteria of optimum values for the successive rigs

$$d_j^l = \sum_{k=1}^{h} y_{jk}^l \qquad \begin{array}{l} l = 1, 2, \ldots, z \\ j = 1, 2, \ldots, m \end{array} \tag{5}$$

– calculating the synthetic value of measure D^l, ($l = 1, 2, \ldots z$) being the relative distances of values in groups of rigs

$$D^l = \sum_{j=1}^{u} d_l^j \qquad l = 1, 2, \ldots h \tag{6}$$

– calculating the synthetic value obtained by multiplying it by established values (W) for respective criteria.

Calculated synthetic measures d_j^l allows for evaluating and comparing particular rigs, whereas synthetic measures D^l allow for comparing groups of rigs [14].

3. REVIEW OF TECHNICAL PARAMETERS OF RIGS USED FOR NORMAL DIAMETER DRILLING WITH THE PERCUSSION-ROTARY METHOD

The technological parameters of rigs currently available on the Polish market for drilling normal diameter wells with the percussion-rotary method from the surface using down-hole hammers were reviewed considering the geological setting of the Upper Silesian region and depth of deposition of post-extraction coal gobs. Taking into account the geological-drilling conditions and the depth of the gobs, selection criteria for rigs which have a significant influence on the efficient realization of wells for coal mine methane from old gobs with high technical-economic drilling parameters were worked out. Among the most important criteria with an influence on the choice of the rig are: initial drilling diameter, mast high, mast capacity, rotary speed, torque, pressure of air compressor, engine power and weight.

High-rate drilling significantly shortens the time of the operations and so limits the number of failures and drilling complications connected with lost mud circulations and maintaining the stability of wellbore walls. Owing to the considerable variation of the depth of old workings and technical parameters of rigs, two depth zones (to 500 m and over 500 m) were distinguished to provide the efficient drilling of production wells. Each depth zone was ascribed rigs, the technical parameters of which would guarantee the realization of wells at high rates of drilling and a low cost. Among the rigs to be used to a depth of 500 m are Atlas Copco T3WDH, Fraste FS300, Massenza MI20, Nordmeyer DSB 3, Prakla RB40 and GEFCO B30. The rigs recommended for drilling wells over 500 m deep are Atlas Copco RD20, Fraste FS500 Massenza MI50, Nordmeyer DSB 5, Prakla RB50 and Wirth B-3A.

4. SELECTING RIGS FOR THE REALIZATION OF PRODUCTION WELLS WITH THE MULTICRITERIA OPTIMIZATION METHOD WITH A SYNTHETIC EVALUATION MEASURE

Rigs used for drilling gas wells from post-extraction coal gobs performed with the percussion-rotary method were selected on the basis of a comparison of the technical parameters of rigs, according to eight criteria. Taking into account the specific character of the realization of this type of wells and the geological and drilling conditions in the place of the planned realization, weights (*W*) were established for each criterion. The criteria, established values and assumed weight values are listed in Table 1.

Table 1

Weight criteria assumed for the evaluation of rigs

Parameter	Weight, *W*
Initial drilling diameter [M]	0.15
Mast height [M]	0.10
Mast capacity [kN]	0.30
Rotary speed [Rpm]	0.05
Torque [kN·m]	0.15
Pressure of air compressor [MPa]	0.10
Weight [kg]	0.05
Engine power [HP]	0.10

The highest validity weight criteria *W* have been assigned for those technical parameters of drilling rigs that have the most important impact on the safe and effective implementation of the designed gas well for simultaneous methane recovery from post-extraction gobs. The technical parameters of all the analyzed rigs which may be used for making gas wells in post-mining areas are presented in Tables 2 and 3.

Table 2

Technical parameters of drilling rigs according to the assumed evaluation criteria used to perform drilling with a down-hole hammer to a depth of 500 m [15]

Parameter	x^l_{jk}	Rig					
		Atlas Copco T3WDH	Fraste FS300	GEFCO B30	Massenza MI20	Nord-meyer DSB 3	Prakla RB40
Initial drilling diameter [M]	x^1_{61}	0.914	1.0	1.5	0.81	1.2	0.9
Mast height [M]	x^1_{62}	11.4	9.9	10.7	10.5	10.7	13.15
Mast capacity [kN]	x^1_{63}	311	140	177	215	200	350
Rotary speed [rpm]	x^1_{64}	145	140	120	150	85	240
Torque [kN·m]	x^1_{65}	7.45	19.2	7.9	20.0	24.0	22.8
Pressure of air compressor [MPa]	x^1_{66}	2.41	3.0	2.41	2.41	1.0	1.4
Weight [kg]	x^1_{67}	31751	31200	30845	31500	26000	28000
Engine power [HP]	x^1_{68}	575	710	550	588	240	434

Table 3

Technical parameters of drilling rigs according to the assumed evaluation criteria used to perform drilling with a down hole hammer to a depth of over 500 m [15]

Parameter	x^l_{jk}	Rig					
		Atlas Copco RD20	Fraste FS500	Massenza MI50	Nord-meyer DSB 5	Prakla RB50	Wirth B-3A
Initial drilling diameter [m]	x^2_{61}	0.66	1.0	1.02	1.5	0.9	1.1
Mast height [m]	x^2_{62}	15.6	14.5	10.6	12.95	17.9	11.0
Mast capacity [kN]	x^2_{63}	490	400	550	400	400	360
Rotary speed [rpm]	x^2_{64}	120	350	150	370	340	80
Torque [kN·m]	x^2_{65}	35.0	43.2	25.0	21.0	31.5	50.0
Pressure of air compressor [MPa]	x^2_{66}	2.4	3.0	3.0	1.4	1.4	1.47
Weight [kg]	x^2_{67}	39000	41000	40500	40000	37320	26000
Engine power [HP]	x^2_{8}	750	755	831	475	440	200

The matrix $[x^l_{jk}]$ of particular criteria values was transformed to the matrix $[y^l_{jk}]$ of standard values for particular rigs based on equation 4 [3, 14]. Then the synthetic values of measures d^l_j, being relative distances between particular criteria of respective optimum values for successive rigs were calculated. Thus the calculated values of measures d^l_j were multiplied by established weight criteria (W) for particular criteria. The last stage of calculations was to determine the synthetic values of measures D^l, being relative distances between respective values in groups of rigs [14].

The results of multicriteria optimization with synthetic evaluation measure for drilling wells performed with a percussion-rotary method with a down-hole hammer are presented in Tables 4–7.

Table 4

Results of the evaluation of rigs for drilling wellbores with a down-hole hammer to a depth of 500 m

Parameter	y^l_{jk}	Rig: Atlas Copco T3WDH	Fraste FS300	GEFCO B30	Massenza MI20	Nord-meyer DSB 3	Prakla RB40	
Initial drilling diameter	y^1_{61}	0.849	0.725	0.000	1.000	0.435	0.870	$D^1 = \sum_{j=l}^{u} d^j_l$
Mast height	y^1_{62}	0.538	1.000	0.754	0.815	0.754	0.000	
Mast capacity	y^1_{63}	0.186	1.000	0.824	0.643	0.714	0.000	
Rotary speed	y^1_{64}	0.613	0.645	0.774	0.581	1.000	0.000	
Torque	y^1_{65}	1.000	0.290	0.973	0.242	0.000	0.073	
Pressure of air compressor	y^1_{66}	0.295	0.000	0.295	0.295	1.000	0.800	
Weight	y^1_{67}	1.000	0.904	0.842	0.956	0.000	0.348	
Engine power	y^1_{68}	0.287	0.000	0.340	0.260	1.000	0.587	
$d^1_j = \sum_{k=1}^{h} y^l_{jk}$		**4.769**	**4.564**	**4.803**	**4.792**	**4.903**	**2.677**	**26.507**

Table 5

Results of the evaluation of rigs for drilling wellbores with a down-hole hammer to a depth over 500 m

Parameter	y^l_{jk}	Rig: Atlas Copco RD20	Fraste FS500	Massenza MI50	Nord-meyer DSB 5	Prakla RB50	Wirth B-3A	
Initial drilling diameter	y^2_{61}	1.000	0.595	0.571	0.000	0.714	0.476	$D^2 = \sum_{j=l}^{u} d^j_l$
Mast height	y^2_{62}	0.315	0.466	1.000	0.678	0.000	0.945	
Mast capacity	y^2_{63}	0.316	0.789	0.000	0.789	0.789	1.000	
Rotary speed	y^2_{64}	0.862	0.069	0.759	0.000	0.103	1.000	
Torque	y^2_{65}	0.517	0.234	0.862	1.000	0.638	0.000	
Pressure of air compressor	y^2_{66}	0.375	0.000	0.000	1.000	1.000	0.956	
Weight	y^2_{67}	0.867	1.000	0.967	0.933	0.755	0.000	
Engine power	y^2_{8}	0.128	0.120	0.000	0.564	0.620	1.000	
$d^2_j = \sum_{k=1}^{h} y^l_{jk}$		**4.380**	**3.274**	**4.159**	**4.965**	**4.619**	**5.378**	**26.776**

Table 6

Results of the evaluation of rigs for drilling wellbores with a down-hole hammer to a depth of 500 m, accounting for the "*w*"coefficient

Parameter	y^l_{jk}	Rig						
		Atlas Copco T3WDH	Fraste FS300	GEFCO B30	Massenza MI20	Nord-meyer DSB 3	Prakla RB40	
Initial drilling diameter	y^1_{61}	0.127	0.109	0.000	0.150	0.065	0.130	
Mast height	y^1_{62}	0.054	0.100	0.075	0.082	0.075	0.000	
Mast capacity	y^1_{63}	0.056	0.300	0.247	0.193	0.214	0.000	$D^1 = \sum_{j=l}^{u} d_l^j \cdot w$
Rotary speed	y^1_{64}	0.031	0.032	0.039	0.029	0.050	0.000	
Torque	y^1_{65}	0.150	0.044	0.146	0.036	0.000	0.011	
Pressure of air compressor	y^1_{66}	0.030	0.000	0.030	0.030	0.100	0.080	
Weight	y^1_{67}	0.050	0.045	0.042	0.048	0.000	0.017	
Engine power	y^1_{68}	0.029	0.000	0.034	0.026	0.100	0.059	
$d_j^1 = \sum_{k=1}^{h} y^l_{jk} \cdot W$		**0.526**	**0.630**	**0.613**	**0.593**	**0.605**	**0.297**	**3.264**

Table 7

Results of the evaluation of rigs for drilling wellbores with a down-hole hammer to a depth over 500 m, accounting for the "*w*"coefficient

Parameter	y^l_{jk}	Rig						
		Atlas Copco RD20	Fraste FS500	Massenza MI50	Nord-meyer DSB 5	Prakla RB50	Wirth B-3A	
Initial drilling diameter	y^2_{61}	0.150	0.089	0.086	0.000	0.107	0.071	
Mast height	y^2_{62}	0.032	0.047	0.100	0.068	0.000	0.095	
Mast capacity	y^2_{63}	0.095	0.237	0.000	0.237	0.237	0.300	$D^2 = \sum_{j=l}^{u} d_l^j \cdot w$
Rotary speed	y^2_{64}	0.043	0.003	0.038	0.000	0.005	0.050	
Torque	y^2_{65}	0.078	0.035	0.129	0.150	0.096	0.000	
Pressure of air compressor	y^2_{66}	0.038	0.000	0.000	0.100	0.100	0.096	
Weight	y^2_{67}	0.043	0.050	0.048	0.047	0.038	0.000	
Engine power	y^2_{8}	0.013	0.012	0.000	0.056	0.062	0.100	
$d_j^2 = \sum_{k=1}^{h} y^l_{jk} \cdot W$		**0.491**	**0.473**	**0.401**	**0.658**	**0.645**	**0.712**	**3.379**

5. CONCLUSIONS

Among the rigs which can be used for the efficient realization of gas wells at depths up to 500 m, the most advantageous is the Prakla RB40 (d_j^l = 2.677), and the FRASTE FS500 (d_j^l = 3.274) at depths exceeding 500 m. Less advantageous in the group of rigs used for drilling to a depth of 500 m are the Fraste FS300 (d_j^l = 4.564), Atlas Copco T3WDH (d_j^l = 4.769), Massenza MI20 (d_j^l = 4.792), GEFCO B30 (d_j^l = 4.803) and Nordmeyer DSB3 (4.903); while in the group of wells used for drilling to depths exceeding 500 m are the Massenza MI50 (d_j^l = 4.159), Atlas Copco RD20 (d_j^l = 4.380), Prakla RB50 (d_j^l = 4.619), Nordmeyer DSB 5 (d_j^l = 4.965) and Wirth B-3A (d_j^l = 5.378).

Considering the geological conditions, the design of wellbores and the weight of particular criteria, the most universal rig to a depth of 500 m is the Prakla RB40 (d_j^l = 0.297) and the Massenza MI 50 (d_j^l = 0.401) to a depth over 500 m. Among the groups of rigs having less favorable parameters used for drilling to 500 m are the Atlas Copco T3WDH (d_j^l = 0.526), Massenza MI20 (d_j^l = 0.593), Nordmeyer DSB3 (d_j^l = 0.605), GEFCO B30 (d_j^l = 0.613) and Fraste FS300 (d_j^l = 0.630). In the group of rigs used for drilling to a depth exceeding 500 m, these are the Fraste FS500 (0.473), Atlas Copco RD20 (d_j^l = 0.491), Prakla RB50 (d_j^l = 0.645), Nordmeyer DSB 5 (d_j^l = 0.658) and Wirth B-3A (d_j^l = 0.712).

REFERENCES

[1] Agency Coalbed Methane Outreach Program in support of the Global Methane Initiative. June 2015.

[2] Dougherty H.N., Karacan C.Ö., Goodman G.V.: *Reservoir diagnosis of longwall gobs through drawdown tests and decline curve analyses of gob gas venthole productions*. International Journal of Rock Mechanics and Mining Sciences, vol. 47, no. 5, 2010, pp. 851–857.

[3] Gonet A., Macuda J.: *Wiertnictwo hydrogeologiczne*. Uczelniane Wydawnictwa Naukowo-Dydaktyczne AGH, Kraków 2004.

[4] Hendel J., Macuda J., Gancarz M.: *Implementation of casing-while-drilling technique for drilling boreholes through unconsolidated formations, crushed during hard coal exploitation. 27th Scientific and Technical Conference Drilling Oil-Gas* 2016: Directions of Development of Oil nad Gas Industry in Poland and in the World. 8th-10th June 2016, Kraków, Poland.

[5] Hendel J., Macuda J.: *Coal mine methane production by vertical boreholes drilled from surface.* SGEM 17th International Multidisciplinary Scientific GeoConference and Expo, Conference Proceedings; 29th June – 5th July 2017, Albena, Bulgaria, pp. 127–133.

[6] Karacan C.Ö.: *Modeling and analysis of gas capture from sealed sections of abandoned coal mines*. International Journal of Coal Geology, vol. 138, 2015, pp. 30–41.

[7] Karacan C.Ö.: *Forecasting gob gas venthole production performances using intelligent computing methods for optimum methane control in longwall coal mines*. International Journal of Coal Geology, vol. 79, no. 4, 2009, pp. 131–144.

[8] Karacan C.Ö.: *Reconciling longwall gob gas reservoirs and venthole production performances using multiple rate drawdown well test analysis*. International Journal of Coal Geology, vol. 80, no. 3, 2009, 181–195.

[9] Karacan C.Ö., Goodman G.V.: *Analyses of geological and hydrodynamic controls on methane emissions experienced in a Lower Kittanning coal mine*. International Journal of Coal Geology, vol. 98, 2012, pp. 110–127.
[10] Karacan C.Ö., Luxbacher K.: *Stochastic modeling of gob gas venthole production performances in active and completed longwall panels of coal mines*. International Journal of Coal Geology, vol. 84, no. 2, 2010, pp. 125–140.
[11] Karacan C.Ö., Olea R.A.: *Sequential Gaussian co-simulation of rate decline parameters of longwall gob gas ventholes*. International Journal of Rock Mechanics and Mining Sciences, vol. 59, 2013, pp. 1–14.
[12] Karacan C.Ö., Ruiz F.A., Cotè M., Phipps S.: *Coal mine methane: a review of capture and utilization practices with benefits to mining safety and to greenhouse gas reduction*. International Journal of Coal Geology, vol. 86, no. 2, 2011, pp. 121–156.
[13] Macuda J., Hendel J.: *Recent drilling techniques and technologies for Coal Mine Methane (CMM) production from gobs*. 26th Scientific and Technical Conference Drilling, Oil, Gas AGH 2015: Future of Oil and Gas Sector. 10–12 June, 2015 Krakow, Poland.
[14] Macuda J.: *Wpływ wybranych czynników techniczno-technologicznych na wskaźniki wiercenia otworów odwadniających na złożu Szczerców*. Faculty of Drilling, Oil and Gas, AGH, Kraków 1990 [PhD thesis].
[15] Materiały katalogowe – Atlas Copco, Fraste, GEFCO, Massenza, Nerdmeyer, Prakla, Wirth.
[16] Palchik V.: *Time-dependent methane emission from vertical prospecting boreholes drilled to abandoned mine workings at a shallow depth*. International Journal of Rock Mechanics and Mining Sciences, vol. 72, 2014, pp. 1–7.
[17] Patyńska R.: *Methodology of estimation of methane emissions from coal mines in Poland*. Studia Geotechnica et Mechanica, vol. 36, no. 1, 2014, pp. 89–101.
[18] Patyńska R.: *Identyfikacja i ocena emisji metanu z węgla kamiennego w Polsce*. Gospodarka Surowcami Mineralnymi – Mineral Resources Menagement, t. 29, z. 1, 2014, pp. 17–34.
[19] Qu Q., Guo H., Loney M.: *Analysis of longwall goaf gas drainage trials with surface directional boreholes*. International Journal of Coal Geology, vol. 156, 2016, pp. 59–73.
[20] Roy B.: *Wielokryterialne wspomaganie decyzji*. WNT, Warszawa 1990.
[21] Schalzel S.J., Karacan C.Ö., Dougherty H., Goodman G.V.R.: *An analysis of reservoir conditions and responses in longwall panel overburden during mining and its effect on gob gas well performance*. Engineering Geology, vol. 127, 2012, pp. 65–74.
[22] Szuflicki M., Malon A., Tymiński M. (red.): *Bilans zasobów złóż kopalin w Polsce wg stanu na 31 XII 2015*. PiG-PiB, Warszawa 2016.
[23] Szwabowski J., Deszcz J.: *Metody wielokryterialnej analizy porównawczej*. Wydawnictwo Politechniki Śląskiej, Gliwice 2001.
[24] Trzaskalik T. (red.): *Analiza wielokryterialna, wybrane zagadnienia*. Wydawnictwo Uniwersytetu Ekonomicznego, Katowice 2013.
[25] U.S. EPA. *Coal Mine Methane Country Profiles*. Prepared by U.S. Environmental Protection 2015.
[26] Wang L., Cheng Y.P.: *Drainage and utilization of Chinese coal mine methane with a coal-methane co-exploitation model: analysis and projections*. Resources Policy, vol. 37, no. 3, 2012, pp. 315–321.