COAL MINE METHANE PRODUCTION BY VERTICAL BOREHOLES DRILLED FROM SURFACE

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ABSTRACT

Large amount of methane trapped in post-coal extraction gobs and galleries in abandonment hard coal mines could be valuable carrier of energy. Methane produced by vertical well could be used to generate both, heat and electricity. However there are many problems with efficiency production of this methane. In dependence of geological structure, coal seams layering and technology used to drilling vertical boreholes from the surface, coal mine methane (CMM) production could be profitable or gives economic losses. Within this article, author described some issues connected with CMM production from abandoned hard coal mines. Author proposed implementation of casing-while-drilling technology with down-hole hammer instead of traditional drilling bit. That technique will decrease hazard of overwhelm borehole wells during drilling into crushed, fractured layers. Based on literature overview and own market research, author presented drilling costs in a function of hypothetical borehole diameter and length.

Keywords: coal mine methane, gobs, methane production, drilling costs

INTRODUCTION

Methane released during coal mine production could be valuable source of energy for both, electrify and heat generation. Methane desorbed from coal is commonly known in four different forms: CBM (Coal Bed Methane) – methane produced from virgin coal seams; VAM (Ventilation Air Methane) – methane and air mixture released by hard coal mines through shafts with methane concentration less than 1%; CMM (Coal Mine Methane) – gas captured by drainage systems and transported by mine's pipelines and, finally, AMM (Abandoned Mine Methane) – gas produced by wells drilled from surface or pipelines installed in shafts from abandoned coal mine. Poland hard coal industry emitted 522,62 million cubic meters of methane as VAM and 316,85 million cubic meters of methane as CMM [1] (total amount of methane emitted in 2015 gives near 840 million cubic meters).

Methane is also one of the green house gasses (GHG) that provide global warming. According EPA (U.S. Environmental Protection Agency) and GMI (Global Methane Initiative) [2] global methane emissions from coal mining industry was 401 million tonnes of CO_2 equivalent (1 tonne of $CH_4 \approx 21$ tonnes of CO_2) in 2000. In 2005 emission growths to 521 million tonnes, and continues increasing to 588 million tonnes in 2010 and 610 million tonnes of CO_2 equivalent (forecast in 2015) respectively. China, as the biggest hard coal producer with over 50% of global share, released also nearly half of global CH_4 emission (321 million tonnes of CO_2 equivalent in 2015) [2]. Dilated statistics of Chinese CMM/VAM/CMM emissions were presented in article [3]. More than 10 million tonnes of CO_2 equivalent per years emitted also: USA, Russia, Ukraine, Australia, Kazakhstan and India [2]. Prediction of methane emission from mining industry in 2020 prepared by EPA [4] was shown on fig. 1.

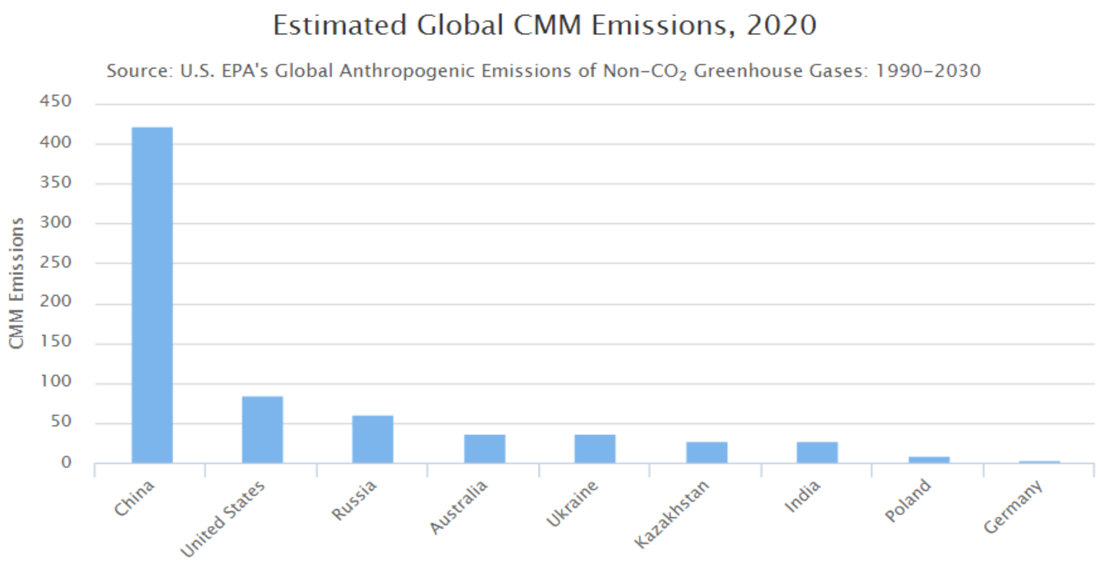

Fig. 1. Estimation of global CMM emission in 2020 in million tones of CO2 equivalent according to EPA [4]

Due to ecological, safety and economic (methane is clean source of energy with heat of combustion value equal to 55 MJ per kilogram) reasons extraction and utilization of methane from working and abandoned mines should be considered and implemented in hard coal mining and post mining areas.

CMM PRODUCTION BY WELLBORE DRILLED FROM SUFRACE

As was mentioned above, CMM and AMM could be produced by pipelines installed in working/abandoned mine shafts or by wellbore drilled to gobs/galleries from surface. In 2010, The Methane to Markets Partnership (M2M) expanded to new global effort known as Global Methane Initiative (GMI) assumed that globally 309 were operating or planed. Worldwide CMM projects by types were shown on fig. 2. American experiences of methane capture, production and utilization from working and abandoned coal mines were presented in papers published by Karacan (2015) [7], Schatzel et al. [8]. Some Australian projects were detailed described in article published by Qu et al., (2016) [9]. Within article [7], author made reservoir modeling studies to shown interactions between wellbore locations and changes in gas emission from coal and leakage from the seals. In paper [9], researchers from NIOSH (National Institute for Occupational Safety and Health, Office of Mine Safety and Health Research) conducted measurements of changes in permeability, methane concentrations and other reservoir parameters in coal seams on gas production from GGVs (Gob Gas Ventholes) drilled in the study panel. Australian investigators analyzed results of trial project of using SDB (Surface Directional Boreholes) to gobs gas drainage [9].

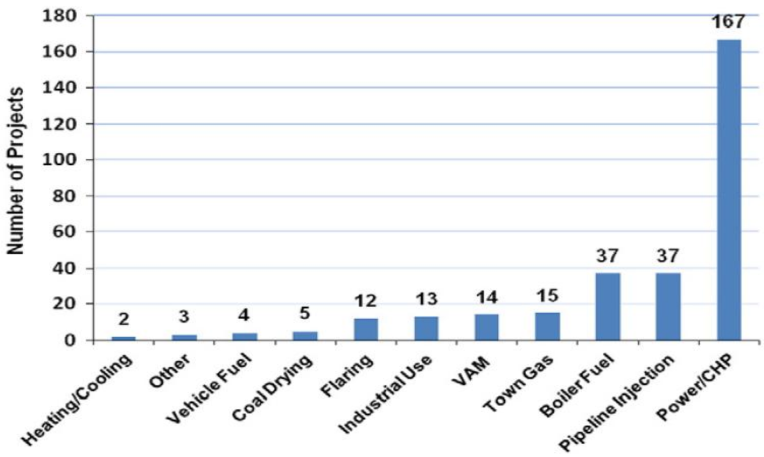

Fig 2. Global CMM projects according to M2M [5] after Karacan et al. [6]

CURRENT TECHNOLOGY FOR GGVS DRILLING

In traditional rotary drilling technology torque on drilling string is transmitted by rotary table. Top-drive systems are also commonly used to drill vertical wellbores (up to 1000 meters). However, drilling a hole with fluid (mud) as a cutting carrier in post-mining areas could provide technical disaster. In many cases, drilling mud is lost in the first unconsolidated, crushed layers formed instead former coal seam. Illustration of that problem is showed on fig. 3.

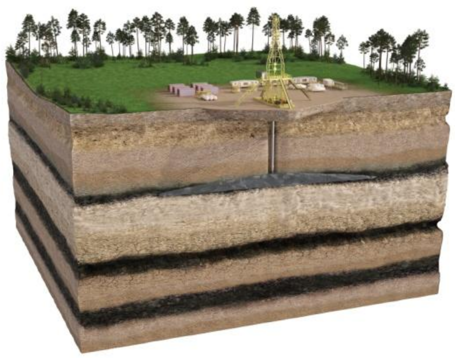

Fig. 3. Drilling fluid lose in post-mining gobs [10]

It will not be problem if the goal is to archive only the first gobs layer or abandoned galleries/pathways. Unfortunately, in Upper Silesian Coal Basin, where author conducted their research program, methane-reach, gassy gobs occurred 500-1000 meters below surface level and upon them, numerous (from 5 to over 15) slightly-gassy or non-gassy (no methane are measured) gobs are commonly presented. In those cases drilling with top hammer or down-the-hole hammer is mostly suggested. Moreover, implementation casing-while-drilling technology could also increase of success probability and cuts total costs of operations [11]. Detailed information about top hammer, down-the-hole-hammer and Casing-while-Drilling (CwD) technology, author presented in paper [10] and [11]. Within the project GEKON (grant no GEKON1/O1/213764/10/2014), author trays to implemented down-the-hole hammer with CwD technology to drilled 5 levels of gobs and start produce methane from all of them.

VERTICAL BOREHOLLES DRILLING COSTS

The comparison of total drilling costs and completion on Polish and American markets was done by Kaliski et al. [12]. The analysis of American experiences of drilling shale gas wells were made based on several papers and reports [13], [14] and [15]. Researchers considered date from thousands shale gas wells and found equation that describes the relationship between drilling cost and borehole depth (1)

$$Drilling\ costs\ [10^6\ USD] = 0{,}1273 \cdot e^{0{,}0008 \cdot h[m]} \qquad (1)$$

where h (as well as in the rest equations) is borehole depth in meters. Coefficient of determination R^2 for this data is equal to 0,9943 so the fitting is nearly perfect. When the article was written, 1 UDS was equal to 3,8945 Polish Zloty (PLN), so the equation (1) could be recalculated to form: (2)

$$Drilling\ costs\ [10^6\ PLN] = 0{,}4958 \cdot e^{0{,}0008 \cdot h[m]} \qquad (2)$$

Between years 2010-2015, when Polish “shale gas fewer” were observed, 70 wells were drilled and completed (up to March 2015). Detailed status of Polish works related to unconventional gas extraction and production is presented in article [16]. Based on boreholes’ expenditures Kaliski et al. [12] searched similar relationship as Americans but for Polish market. This function could be expressed: (3)

$$Drilling\ costs\ [10^6\ PLN] = 8{,}134 \cdot e^{0{,}0004 \cdot h[m]} \qquad (3)$$

Because of much less number of wellbores drilled in Poland, the relationship between costs and depth could not be as good and precise as for North American market, and the coefficient of determination is equal to 0,7913 [12]. For comparison costs of wellbores on both markets are shown in table 1.

Table 1. Comparison of drilling costs on U.S. and Polish markets. Based on [12]

Wellbore depth [m]	Drilling costs on North American market [mln PLN]	Drilling costs on Polish market [mln PLN]
500 m	0,740	9,935
1000 m	1,103	12,135
1500 m	1,646	14,821
2000 m	2,456	18,103
2500 m	3,663	22,111
3000 m	5,465	27,006
3500 m	8,153	32,985
4000 m	12,163	40,288
4500 m	18,145	49,208
5000 m	27,070	60,103

The reason of huge differences of expenses paid for drilling operation is status of drilling rotary rigs working/available to drilling on field. In October-December 2011, during extraction peak, in North America area, more than 900 gas rotary rigs were working continuously. For the other hand, in Poland between 2010-2015 only 4-5 companies (in majority grouped in Polish Oil and Gas Company – PGNiG Ltd.), with total capacity of several drilling rigs were able to made borehole deeper than 2000 m.

This monopolization of side operator's market caused few times highest prices of boreholes in Poland. However, market of companies which are able to drill shallower boreholes (to max. 1000 m) is much more dispersed. Author was trying to estimate costs, sent letters of inquiry to several local southern-Polish geological and geotechnical companies. Researcher was asking them about drilling 300-700 meters boreholes with using various casings diameters and different technology. Letters of inquiry were sent to followed company: Algeo Ltd., Chrobok Ltd., Dalbis Ltd., DMM Ltd., G-Drilling Ltd., Hydroel Ltd and Hydropol Ltd. Two various borehole depths in four different localizations were considered. 7 and 4 ½ inch production casing boreholes drilled using classic mud or air-powered down-the-hole hammer techniques were taken into account. Unfortunately, only 3 companies sent back offers of performance of several boreholes cases. Questionnaire results are shown on fig.4.

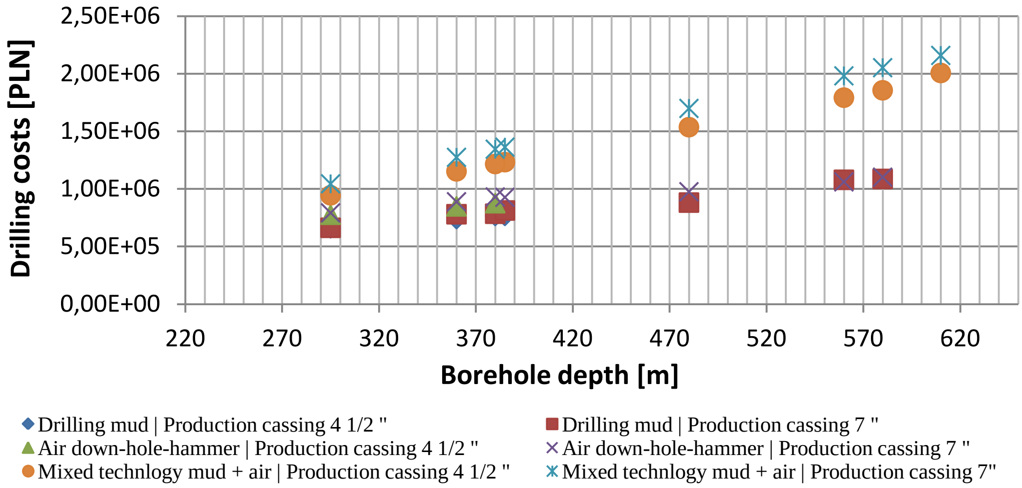

Fig. 4. Drilling prices collected get into performance offers procedure

In comparison, on fig.5, North American and Polish drilling costs of shale gas wells (> 1000 m depth) were added (red and blue lines).

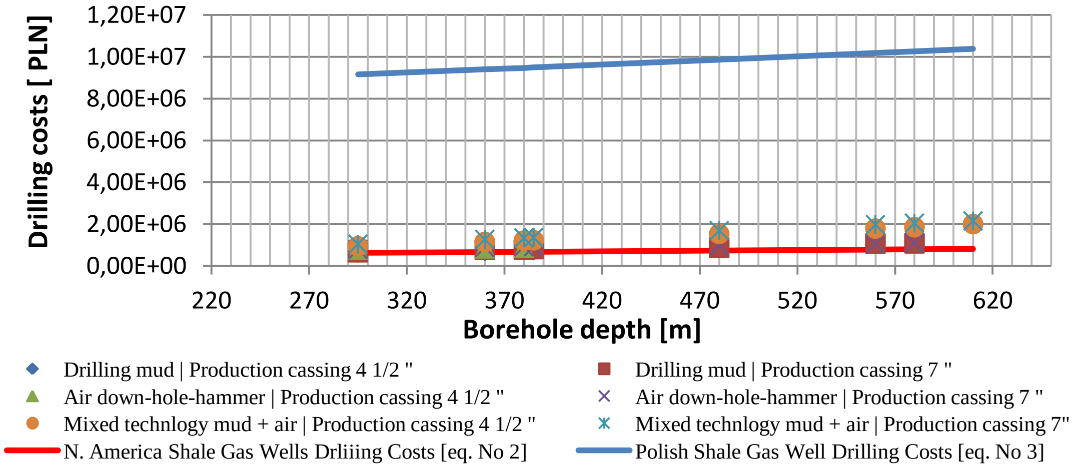

Fig. 5. Drliing costs of shallow wells (<1000 m. dots) in comparison with deep shale gas wells cost (lines)

CONCLUSION

Within this article short brief of occurrences and possibilities of methane production projects were discussed. Author presented some statistics of CBM/CMM/AMM worldwide projects that are conducted. Current technology of drilling boreholes to gobs and technical problems that could occurred are listed. In this paper, author focused on well drilling cost as a major and crucial factor of economic efficiency of CBM/CMM projects. On the fig. 5 huge differences of drilling costs between Polish and North American market could be observed. As was mentioned before, gap in price is caused by low availability of drilling rig. Expenditures for shallow well (<1000 m) is much lower that increase benefits from CBM/AMM wells.

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