Modelling of computational fluid dynamics of gas dynamic processes on longwall panel during underground mining of flat gassy coal multi-seam

A A Sidorenko, V V Ivanov, S A Sidorenko

Saint-Petersburg Mining University, 2, 21 linia, Vasilievski ostrov, Saint-Petersburg, 199106, Russia

E-mail: Sidorenkoaa@mail.ru

Abstract. In the paper, results of numerical modeling with use of a method of computational fluid dynamics of aerogasdynamic processes on the longwall panel of the coal mines during mining flat gassy coal multi-seam are presented. The three-dimensional aerogasdynamic model of the longwall panel developed by the authors is presented. Numerical research is conducted for conditions of flat thick seam mining in mine V.D. Yalysky. As a result of research, the low efficiency of use of the vertical drainage goaf wells located from the headgate is established and recommendations about decrease in the number of wells for reduction of cost of their drilling are made. Results of the research can be used for justification of ventilation and gas drainage during gassy multi-seam underground mining.

1. Introduction
Use of the modern reliable and high-performance equipment in coal mines provides a significant increase in productivity of mining [1-4]. Productivity of longwall has increased in Russia 2-5 times in recent years. Also growth of width and length of longwall panels is observed that during mining of gassy seams leads to increase in methane emission from the underworked and overworked seams. Increase in productivity of longwall and the sizes of longwall panels lead to significant growth of volumes of the methane which is emitted in entries of the longwall panel. The considerable gas emission of the longwall panel demands application of effective ways of gas management for safety of mining [5-10]. Now ways of gas drainage of the gob by vertical wells (drilled from the surface) are successfully applied, but the cost of drilling of such wells has already exceeded the costs of development of the longwall panel and continues to grow with increase in depth of mining. In this regard a crucial task is the choice of design of vertical vent wells for providing effective methane management at the minimum costs of well-drilling. In mine conditions, various designs of wells, high cost of drilling and the increased danger of metane managment have been already tested not to allow making experiments in mines. In that case application of modeling of three-dimensional computational fluid dynamics which allows studying influence of various geological and mining factors on effective management of gas which is effective.

This paper represents results of modeling of ventilation systems and gas drainage for justification of parameters of techniques of effective gas management.
2. Methods
For justification of parameters of gas drainage, techniques of the goaf methods of computational fluid were used. The efficiency of application of such methods for the solution of problems of design of drainage wells was noted by many authors [11-15]. The three-dimensional aero gasdynamic model of the longwall panel is developed on the basis of approaches of other authors [13-15]. Modeling is carried out in scale 1:1. The model includes (figure 1): the longwall, the goaf, the longwall panel entries, vertical drainage wells, horizontal drainage wells drilled through pillar coal from the parallel entry. Methane emission was set as uniform: from a coal face of the seam, from the underworked and overworked coal-rock massif (figure 1).

![Aerogasdynamic model of a longwall panel.](image)

Figure 1. Aerogasdynamic model of a longwall panel.

The need for various permeability of the goaf is specified by many researchers [11-15]. In the model the permeability of the site of the goaf behind a longwall reached $5 \times 10^{-6}$ m², and in the other goaf - decreased to $3 \times 10^{-8}$ m². The permeability of the zone of the goaf adjoining a longwall has a considerable impact on efficiency of gas drainage and ventilation as it determines the size of leak of air. Mine observations (the mine of V.D. Yalevsky) show presence of residual section of entry behind a longwall, air, free for pass, that has a considerable impact on aerodynamic processes. Preservation of a part of entry behind a longwall was considered when developing the model by the increased permeability.

3. Results and Discussion
As a result of executed numerical researches with use of the developed aerogasdynamic model, fields of concentration of methane, oxygen, air speeds and also ways of the movement of air in entries of the longwall panel and in the goaf are received with various parameters of gas drainage techniques. Seam 52 mined at the mine V.D. Yalevsky is prone to spontaneous ignition of coal. In this connection, the distribution of oxygen in the goaf is of considerable interest. However, the applied techniques of ventilation and goaf drainage exclude spontaneous combustion of coal due to the high rate of moving of the longwall and ventilation of a limited area of the goaf near the longwall, so the issues of substantiation of ventilation schemes when mining coal seams prone to spontaneous ignition are not considered in this paper.

As an example of results of modeling in figure 2, fields of concentration of methane on longwall panel 5209 during mining concerning the use of three rows of vent wells are presented. Figure 2,a shows fields of concentration of methane at the height of 2 m from the seam floor. Apparently in figure 2,a in the considered section, goaf does not exceed 20% and the maximum concentration is observed at drainage wells from tailgate. In figure 2,b fields of concentration of methane at the height of 22 m from...
the seam floor are presented. From figure 2 it is visible that the main volumes of methane are in the top part of goaf that is accounted several times by big gas emission from the underworked seams. Figure 2 allows drawing a conclusion that the main volumes of methane are removed; the wells are located at tailgate (concentration of methane reaches 52%). The smallest concentration of methane (17%) is observed at the distant well, located near the headgate.

The executed research show that work of the wells located near the headgate is less effective; therefore drilling only wells of the same kind can be recommended from tailgate.

![Figure 2. Concentration of methane (four working wells), %.

In figure 3 distribution of methane in the location only of drainage wells of the same kind from tailgate is presented. Numerical modeling showed a possibility of application of such drainage techniques at gas emission of the goaf to 90 m³/min on condition of effective drainage with use of horizontal wells, the consumption of methane-air mix of which has to make not less than 200 m³/min.

It should be noted that at the mine V. D. Yalevsky there is application of experience of gas-exhausting fans, providing the possibility of removal via a ventilation connection of up to 1000 m³/min. Application of gas-exhausting fans with great performance provides an efficient removal of large volumes of methane-air mixture (with methane concentration up to 3.5%) from the part of the goaf behind the longwall. The use of gas-exhausting fans provides the use of four degassing wells to increase the productivity on the longwall up to 60,000 tons per day with gas emission at the longwall panel up to 240 m³/min.

![Figure 3. Concentration of methane (two working wells), %.

The received results of mine research completely correspond to results of mine observations that confirms a possibility of application of a numerical method for justification of parameters of ventilation and gas drainage.
4. Conclusion
The executed research allowed drawing a conclusion on low overall performance of the vertical drainage wells located from headgate and recommending application only of two vertical drainage wells located in the tailgate. The possibility of application of only two vertical drainage wells was confirmed by the results of numerical modeling. It should be noted that application of two vertical drainage wells is possible only on condition of consumption of the methane-air mix in vertical wells of not less than 80 m$^3$/min (each well) and total consumption of methane-air mix in horizontal drainage wells of not less than 200 m$^3$/min. However, application of such gas drainage technique is possible during methane emission in goaf of not more than 90 m$^3$/min.

Thus, the executed research showed a possibility of design of ventilation and gas drainage during flat gassy coal multi-seam underground mining.

5. Acknowledgments
The authors express gratitude for the help in carrying out research to Andrey Mikhaylovich Cherdantsev, the chief engineer of mine V.D. Yalevsky.

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